

IPC-A-610D

Acceptability of Electronic Assemblies

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A standard developed by IPC

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- Include a feedback system on use and problems for future improvement

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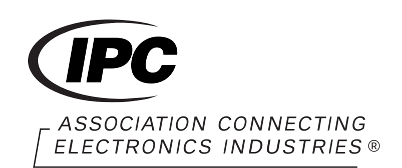
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Acceptability of Electronic Assemblies

Developed by the IPC Task Group (7-31b) of the Product Assurance Subcommittee (7-30) of IPC



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Users of this publication are encouraged to participate in the development of future revisions.

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TABLES

Foreword

The following topics are addressed in this section:

Foreword

If a conflict occurs between the English and translated versions of this document, the English version will take precedence.

1.1 Scope

This standard is a collection of visual quality acceptability requirements for electronic assemblies.

This document presents acceptance requirements for the manufacture of electrical and electronic assemblies. Historically, electronic assembly standards contained a more comprehensive tutorial addressing principles and techniques. For a more complete understanding of this document's recommendations and requirements, one may use this document in conjunction with IPC-HDBK-001, IPC-HDBK-610, and IPC J-STD-001.

The criteria in this standard are not intended to define processes to accomplish assembly operations nor is it intended to authorize repair/modification or change of the customer's product. For instance, the presence of criteria for adhesive bonding of components does not imply/authorize/require the use of adhesive bonding, and the depiction of a lead wrapped clockwise around a terminal does not imply/authorize/require that all leads/wires be wrapped in the clockwise direction.

IPC-A-610 has criteria outside the scope of IPC J-STD-001 defining handling, mechanical and other workmanship requirements. Table 1-1 is a summary of related documents.

Table 1-1 Summary of Related Documents

Document Purpose	Spec.#	Definition
Design Standard	IPC-2220 (Series) IPC-SM-782 IPC-CM-770	Design requirements reflecting three levels of complexity (Levels A, B, and C) indicating finer geometries, greater densities, more process steps to produce the product. Component and Assembly Process Guidelines to assist in the design of the bare board and the assembly where the bare board processes concentrate on land patterns for surface mount and the assembly concentrates on surface mount and through-hole principles which are usually incorporated into the design process and the documentation.
End Item Documentation	IPC-D-325	Documentation depicting bare board specific end product requirements designed by the customer or end item assembly requirements. Details may or may not reference industry specifications or workmanship standards as well as customer's own preferences or internal standard requirements.
End Item Standards	IPC J-STD-001	Requirements for soldered electrical and electronic assemblies depicting minimum end product acceptable characteristics as well as methods for evaluation (test methods), frequency of testing and applicable ability of process control requirements.
Acceptability Standard	IPC-A-610	Pictorial interpretive document indicating various characteristics of the board and/or assembly as appropriate relating to desirable conditions that exceed the minimum acceptable characteristics indicated by the end item performance standard and reflect various out-of-control (process indicator or defect) conditions to assist the shop process evaluators in judging need for corrective action.
Training Programs (Optional)		Documented training requirements for teaching and learning process procedures and techniques for implementing acceptance requirements of either end item standards, acceptability standards, or requirements detailed on the customer documentation.
Rework and Repair	IPC-7711A/ IPC-7721A	Documentation providing the procedures to accomplish conformal coating and component removal and replacement, solder resist repair, and modification/repair of laminate material, conductors, and plated-through holes.

Foreword (cont.)

IPC-HDBK-610 is a supporting document that provides information regarding the intent of this specification content and explains or amplifies the technical rationale for transition of limits through Target to Defect condition criteria. In addition, supporting information is provided to give a broader understanding of the process considerations that are related to performance but not commonly distinguishable through visual assessment methods.

The explanations provided in this companion resource should be useful in determining disposition of conditions identified as Defect, processes associated with Process Indicators, as well as answering questions regarding clarification in use and application for defined content of this specification. Contractual reference to this standard does not additionally impose the content of IPC-HDBK-610 unless specifically referenced in contractual documentation.

1.2 Purpose

The visual standards in this document reflect the requirements of existing IPC and other applicable specifications. In order for the user to apply and use the content of this document, the assembly/product should comply with other existing IPC requirements, such as IPC-SM-782, IPC-2220 (Series), IPC-6010 (Series) and IPC-A-600. If the assembly does not comply with these or with equivalent requirements, the acceptance criteria needs to be defined between the customer and supplier.

The illustrations in this document portray specific points noted in the title of each page. A brief description follows each illustration. It is not the intent of this document to exclude any acceptable procedure for component placement or for applying flux and solder used to make the electrical connection; however, the methods used must produce completed solder joints conforming to the acceptability requirements described in this document.

In the case of a discrepancy, the description or written criteria always takes precedence over the illustrations.

1.3 Specialized Designs

IPC-A-610, as an industry consensus document, cannot address all of the possible components and product design combinations. Where uncommon or specialized technologies are used, it may be necessary to develop unique acceptance criteria. However, where similar characteristics exist, this document may provide guidance for product acceptance criteria. Often, unique definition is necessary to consider the specialized characteristics while considering product performance criteria. The development should include customer involvement and, for Class 3, needs to have customer consent, and the criteria should include agreed definition of product acceptance.

Whenever possible these criteria should be submitted to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this standard.

1.4 Terms & Definitions

Items noted with an * are quoted from IPC-T-50.

1.4.1 Classification

The customer (user) has the ultimate responsibility for identifying the class to which the assembly is evaluated.

Documentation that specifies the applicable class for the assembly under inspection needs to be provided to the inspector.

Accept and/or reject decisions need to be based on applicable documentation such as contracts, drawings, specifications, standards and reference documents. Criteria defined in this document reflect three classes, which are as follows:

Class 1 — General Electronic Products

Includes products suitable for applications where the major requirement is function of the completed assembly.

Class 2 — Dedicated Service Electronic Products

Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically the end-use environment would not cause failures.

Class 3 — High Performance Electronic Products

Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

1.4.2 Acceptance Criteria

When IPC-A-610 is cited or required by contract as a standalone document for inspection and/or acceptance, the requirements of IPC J-STD-001 ''Requirements for Soldered Electrical and Electronic Assemblies'' do not apply unless separately and specifically required.

In the event of conflict, the following order of precedence applies:

1. Procurement as agreed and documented between customer and supplier.
2. Master drawing or master assembly drawing reflecting the customer's detailed requirements.

Foreword (cont.)

3. When invoked by the customer or per contractual agreement, IPC-A-610.
4. Other documents to extent specified by the customer.

The user (customer) has the responsibility to specify acceptance criteria. If no criteria is specified, required, or cited, then best manufacturing practice applies. When IPC J-STD-001 and IPC-A-610 or other related documents are cited, the order of precedence is to be defined in the procurement documents.

Criteria are given for each class in four levels of acceptance: Target Condition, Acceptable Condition, and either Defect Condition or Process Indicator Condition.

Unless otherwise specified, criteria in this standard are applicable for solid wire/component leads or stranded wire.

1.4.2.1 Target Condition

A condition that is close to perfect/preferred, however, it is a desirable condition and not always achievable and may not be necessary to ensure reliability of the assembly in its service environment.

1.4.2.2 Acceptable Condition

This characteristic indicates a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment.

1.4.2.3 Defect Condition

A defect is a condition that may be insufficient to ensure the form, fit or function of the assembly in its end use environment. Defect conditions need to be dispositioned by the manufacturer based on design, service, and customer requirements. Disposition may be to rework, repair, scrap, or use as is. Repair or ''use as is'' may require customer concurrence.

A defect for Class 1 automatically implies a defect for Class 2 and 3. A defect for Class 2 implies a defect for Class 3.

1.4.2.4 Process Indicator Condition

A process indicator is a condition (not a defect) which identifies a characteristic that does not affect the form, fit or function of a product.

- Such condition is a result of material, design and/or operator/machine related causes that create a condition that neither fully meets the acceptance criteria nor is a defect.
- Process indicators should be monitored as part of the process control system. When the number of process indicators indicate abnormal variation in the process or identify an undersirable trend, then the process should be analyzed. This may result in action to reduce the variation and improve yields.
- Disposition of individual process indicators is not required and affected product should be used as is.
- Process control methodologies are to be used in the planning, implementation and evaluation of the manufacturing processes used to produce soldered electrical and electronic assemblies. The philosophy, implementation strategies, tools and techniques may be applied in different sequences depending on the specific company, operation, or variable under consideration to relate process control and capability to end product requirements. The manufacturer needs to maintain objective evidence of a current process control/continuous improvement plan that is available for review.

1.4.2.5 Combined Conditions

Cumulative conditions must be considered in addition to the individual characteristics for product acceptability even though they are not individually considered defective. The significant number of combinations that could occur does not allow full definition in the content and scope of this specification but manufacturers should be vigilant for the possibility of combined and cumulative conditions and their impact upon product performance.

Conditions of acceptability provided in this specification are individually defined and created with separate consideration for their impact upon reliable operation for the defined production classification. Where related conditions can be combined, the cumulative performance impact for the product may be significant; e.g., minimum solder fillet quantity when combined with maximum side overhang and minimum end overlap may cause a significant degradation of the mechanical attachment integrity. The manufacturer is responsible for identification of such conditions.

1.4.2.6 Conditions Not Specified

Conditions that are not specified as defective or as a process indicator may be considered acceptable unless it can be established that the condition affects user defined form, fit, function.

1.4.3 Board Orientation

The following terms are used throughout this document to determine the board side:

1.4.3.1 *Primary Side

That side of a packaging and interconnecting structure (PCB) that is so defined on the master drawing. (It is usually the side that contains the most complex or the most number of com-

Foreword (cont.)

ponents. This side is sometimes referred to as the component side or solder destination side in through-hole mounting technology.)

1.4.3.2 *Secondary Side

That side of a packaging and interconnecting structure (PCB) that is opposite the primary side. (This side is sometimes referred to as the solder side or solder source side in through-hole mounting technology.)

1.4.3.3 Solder Source Side

The solder source side is that side of the PCB to which solder is applied. The solder source side is normally the secondary side of the PCB when wave, dip, or drag soldering are used. The solder source side may be the primary side of the PCB when hand soldering operations are conducted. The source/destination side must be considered when applying some criteria, such as that in Tables 7-3, 7-6 and 7-7.

1.4.3.4 Solder Destination Side

The solder destination side is that side of the PCB that the solder flows toward in a through-hole application. The destination is normally the primary side of the PCB when wave, dip or drag soldering is used. The destination side may be the secondary side of the PCB when hand-soldering operations are conducted. The source/destination side must be considered when applying some criteria, such as that in Tables 7-3, 7-6 and 7-7.

1.4.4 *Cold Solder Connection

A solder connection that exhibits poor wetting and that is characterized by a grayish porous appearance. (This is due to excessive impurities in the solder, inadequate cleaning prior to soldering, and/or the insufficient application of heat during the soldering process.)

1.4.5 Electrical Clearance

Throughout this document the minimum spacing between noncommon uninsulated conductors (e.g., patterns, materials, hardware, or residue) is referred to as ''minimum electrical clearance.'' It is defined in the applicable design standard or on the approved or controlled documentation. Insulating material needs to provide sufficient electrical isolation. In the absence of a known design standard use Appendix A (derived from IPC-2221). Any violation of minimum electrical clearance is a defect condition.

1.4.6 High Voltage

The term ''high voltage'' will vary by design and application. The high voltage criteria in this document are only applicable when specifically required in the drawings/procurement documentation.

1.4.7 Intrusive Solder

A process in which the solder paste for the through-hole components is applied using a stencil or syringe to accommodate through-hole components that are inserted and reflow-soldered together with the surface-mount components.

1.4.8 *Leaching

The loss or removal of a basis metal or coating during a soldering operation.

1.4.9 Meniscus (Component)

Sealant or encapsulant on a lead, protruding from the seating plane of the component. This includes materials such as ceramic, epoxy or other composites, and flash from molded components.

1.4.10 Pin-in-Paste

See Intrusive Solder.

1.4.11 Wire Diameter In this document, wire diameter (D) is the overall diameter of conductor including insulation.

1.5 Examples and Illustrations

Many of the examples (illustrations) shown are grossly exaggerated in order to depict the reasons for this classification.

It is necessary that users of this standard pay particular attention to the subject of each section to avoid misinterpretation.

1.6 Inspection Methodology

Accept and/or reject decisions must be based on applicable documentation such as contract, drawings, specifications and referenced documents.

The inspector does not select the class for the assembly under inspection (see 1.4.1). Documentation that specifies the applicable class for the assembly under inspection is to be provided to the inspector.

Automated Inspection Technology (AIT) is a viable alternative to visual inspection and complements automated test equipment. Many of the characteristics in this document can be inspected with an AIT system. IPC-AI-641 ''User's Guidelines for Automated Solder Joint Inspection Systems'' and IPC-AI-642 ''User's Guidelines for Automated Inspection of Artwork, Inner-layers, and Unpopulated PCBs'' provide more information on automated inspection technologies.

If the customer desires the use of industry standard requirements for frequency of inspection and acceptance, J-STD-001 is recommended for further soldering requirement details.

Foreword (cont.)

1.7 Verification of Dimensions

The actual measurements provided in this document (i.e., specific part mounting and solder fillet dimensions and determination of percentages) are not required except for referee purposes. All dimensions in this standard are expressed in SI (System International) units (with Imperial English equivalent dimensions provided in brackets).

1.8 Magnification Aids and Lighting

For visual inspection, some individual specifications may call for magnification aids for examining printed board assemblies.

The tolerance for magnification aids is ± 15% of the selected magnification power. Magnification aids, if used for inspection need to be appropriate with the item being inspected. Lighting needs to be adequate for the magnification aids used. Unless magnification requirements are otherwise specified by contractual documentation, the magnifications in Table 1-2 and Table 1-3 are determined by the item being inspected.

Referee conditions are used to verify product rejected at the inspection magnification power. For assemblies with mixed land widths, the greater magnification may be used for the entire assembly.

Table 1-2 Inspection Magnification (Land Width)

Land Widths or Land Diameters[1]	Magnification Power	
	Inspection Range	Maximum Referee
>1.0 mm [0.0394 in]	1.5X to 3X	4X
>0.5 to ≤1.0 mm [0.0197 to 0.0394 in]	3X to 7.5X	10X
≥0.25 to ≤0.5 mm [0.00984 to 0.0197 in]	7.5X to 10X	20X
<0.25 mm [0.00984 in]	20X	40X

Note 1: A portion of a conductive pattern used for the connection and/or attachment of components.

Table 1-3 Magnification Aid Applications - Other

Cleanliness (cleaning processes)	Magnification not required, see Note 1
Cleanliness (no-clean processes per 10.4.4)	Note 1
Conformal Coating/ Encapsulation	Notes 1,2
Other (Component and wire damage, etc.)	Note 1

Note 1: Visual inspection may require the use of magnification, e.g., when fine pitch or high density assemblies are present, magnification may be needed to determine if contamination affects form, fit or function.
Note 2: If magnification is used it is limited to 4X maximum.

2 Applicable Documents

The following documents of the issue currently in effect form a part of this document to the extent specified herein.

2.1 IPC Documents[1]

IPC-HDBK-001 Handbook & Guide to Supplement J-STD-001 with Amendment 1

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-CH-65 Guidelines for Cleaning of Printed Boards and Assemblies

IPC-D-279 Design Guidelines for Reliable Surface Mount Technology Printed Board Assemblies

IPC-D-325 Documentation Requirements for Printed Boards

IPC-DW-425 Design and End Product Requirements for Discrete Wiring Boards

IPC-DW-426 Guidelines for Acceptability of Discrete Wiring Assemblies

IPC-TR-474 An Overview of Discrete Wiring Techniques

IPC-A-600 Acceptability of Printed Boards

IPC-HDBK-610 Handbook and Guide to IPC-A-610 (Includes IPC-A-610B to C Comparison)

IPC/WHMA-A-620 Requirements & Acceptance for Cable & Wire Harness Assemblies

IPC-AI-641 User's Guidelines for Automated Solder Joint Inspection Systems

IPC-AI-642 User's Guidelines for Automated Inspection of Artwork, Inner-layers, and Unpopulated PWBs

IPC-TM-650 Test Methods Manual

IPC-CM-770 Component Mounting Guidelines for Printed Boards

IPC-SM-782 Surface Mount Design Land Pattern Standard

IPC-CC-830 Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies

IPC-HDBK-830 Guidelines for Design, Selection and Application of Conformal Coatings

IPC-SM-840 Qualification and Performance of Permanent Solder Mask

IPC-SM-785 Guidelines for Accelerated Reliability Testing of Surface Mount Attachments

IPC-2220 (Series) IPC 2220 Design Standards Series

IPC-7095 Design and Assembly Process Implementation for BGAs

IPC-6010 (Series) IPC-6010 Qualification and Performance Series

IPC-7711A/7721A Rework, Repair and Modification of Electronic Assemblies

IPC-9701 Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments

2.2 Joint Industry Documents[2]

IPC J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

IPC/EIA J-STD-002 Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires

IPC/EIA J-STD-003 Solderability Tests for Printed Boards

J-STD-004 Requirements for Soldering Fluxes

IPC/JEDEC J-STD-020 Moisture/Reflow Sensitivity Classification for Plastic Integrated Circuit Surface Mount Devices

IPC/JEDEC J-STD-033 Standard for Handling, Packing, Shipping and Use of Moisture Sensitive Surface Mount Devices

1. www.ipc.org
2. www.ipc.org

2.3 EOS/ESD Association Documents[3]

ANSI/ESD S8.1 ESD Awareness Symbols

ANSI/ESD-S-20.20 Protection of Electrical and Electronic Parts, Assemblies and Equipment

2.4 Electronics Industries Alliance Documents[4]

EIA-471 Symbol and Label for Electrostatic Sensitive Devices

2.5 International Electrotechnical Commission Documents[5]

IEC/TS 61340-5-1 Protection of Electronic Devices from Electrostatic Phenomena - General Requirements

IEC/TS 61340-5-2 Protection of Electronic Devices from Electrostatic Phenomena - User Guide

4

3. www.esda.org
4. www.eia.org
5. www.iec.ch

Protecting the Assembly – EOS/ESD and Other Handling Considerations

The following topics are addressed in this section.

3.1 EOS/ESD Prevention

Electrostatic Discharge (ESD) is the rapid transfer of a static electric charge from one object to another of a different potential that was created from electrostatic sources. When an electrostatic charge is allowed to come in contact with or close to a sensitive component it can cause damage to the component.

Electrical Overstress (EOS) is the internal result of an unwanted application of electrical energy that results in damaged components. This damage can be from many different sources, such as electrically powered process equipment or ESD occurring during handling or processing.

Electrostatic Discharge Sensitive (ESDS) components are those components that are affected by these high-electrical energy surges. The relative sensitivity of a component to ESD is dependent upon its construction and materials. As components become smaller and operate faster, the sensitivity increases.

ESDS components can fail to operate or change in value as a result of improper handling or processing. These failures can be immediate or latent. The result of immediate failure can be additional testing and rework or scrap. However the consequences of latent failure are the most serious. Even though the product may have passed inspection and functional test, it may fail after it has been delivered to the customer.

It is important to build protection for ESDS components into circuit designs and packaging. In the manufacturing and assembly areas, work is often done with unprotected electronic assemblies (such as test fixtures) that are attached to the ESDS components. It is important that ESDS items be removed from their protective enclosures only at EOS/ESD safe workstations within Electrostatic Protected Areas (EPA). This section is dedicated to safe handling of these unprotected electronic assemblies.

Information in this section is intended to be general in nature. Additional information can be found in IPC J-STD-001, ANSI/ESD-S-20.20 and other related documents.

3.1.1 EOS/ESD Prevention – Electrical Overstress (EOS)

Electrical components can be damaged by unwanted electrical energy from many different sources. This unwanted electrical energy can be the result of ESD potentials or the result of electrical spikes caused by the tools we work with, such as soldering irons, soldering extractors, testing instruments or other electrically operated process equipment. Some devices are more sensitive than others. The degree of sensitivity is a function of the design of the device. Generally speaking, higher speed and smaller devices are more susceptible than their slower, larger predecessors. The purpose or family of the device also plays an important part in component sensitivity. This is because the design of the component can allow it to react to smaller electrical sources or wider frequency ranges. With today's products in mind, we can see that EOS is a more serious problem than it was even a few years ago. It will be even more critical in the future.

When considering the susceptibility of the product, we must keep in mind the susceptibility of the most sensitive component in the assembly. Applied unwanted electrical energy can be processed or conducted just as an applied signal would be during circuit performance.

Before handling or processing sensitive components, tools and equipment need to be carefully tested to ensure that they do not generate damaging energy, including spike voltages. Current research indicates that voltages and spikes less than 0.5 volt are acceptable. However, an increasing number of extremely sensitive components require that soldering irons, solder extractors, test instruments and other equipment must never generate spikes greater than 0.3 volt.

As required by most ESD specifications, periodic testing may be warranted to preclude damage as equipment performance may degrade with use over time. Maintenance programs are also necessary for process equipment to ensure the continued ability to not cause EOS damage.

EOS damage is certainly similar in nature to ESD damage, since damage is the result of undesirable electrical energy.

3.1.2 EOS/ESD Prevention – Electrostatic Discharge (ESD)

Table 3-1 Typical Static Charge Sources

Work surfaces	Waxed, painted or varnished surfaces Untreated vinyl and plastics Glass
Floors	Sealed concrete Waxed or finished wood Floor tile and carpeting
Clothes and personnel	Non-ESD smocks Synthetic materials Non-ESD Shoes Hair
Chairs	Finished wood Vinyl Fiberglass Nonconductive wheels
Packaging and handling materials	Plastic bags, wraps, envelopes Bubble wrap, foam Styrofoam Non-ESD totes, trays, boxes, parts bins
Assembly tools and materials	Pressure sprays Compressed air Synthetic brushes Heat guns, blowers Copiers, printers

Table 3-2 Typical Static Voltage Generation

Source	10-20% humidity	65-90% humidity
Walking on carpet	35,000 volts	1,500 volts
Walking on vinyl flooring	12,000 volts	250 volts
Worker at a bench	6,000 volts	100 volts
Vinyl envelopes (Work Instructions)	7,000 volts	600 volts
Plastic bag picked up from the bench	20,000 volts	1,200 volts
Work chair with foam pad	18,000 volts	1,500 volts

The best ESD damage prevention is a combination of preventing static charges and eliminating static charges if they do occur. All ESD protection techniques and products address one or both of the two issues.

ESD damage is the result of electrical energy that was generated from static sources either being applied or in close proximity to ESDS devices. Static sources are all around us. The degree of static generated is relative to the characteristics of the source. To generate energy, relative motion is required. This could be contacting, separation, or rubbing of the material.

Most of the serious offenders are insulators since they concentrate energy where it was generated or applied rather than allowing it to spread across the surface of the material. See Table 3-1. Common materials such as plastic bags or Styrofoam containers are serious static generators and as such are not to be allowed in processing areas especially static safe/ Electrostatic Protected Areas (EPA). Peeling adhesive tape from a roll can generate 20,000 volts. Even compressed air nozzles that move air over insulating surfaces generate charges.

Destructive static charges are often induced on nearby conductors, such as human skin, and discharged into conductors on the assembly. This can happen when a person having an electrostatic charge potential touches a printed board assembly. The electronic assembly can be damaged as the discharge passes through the conductive pattern to an ESDS component. Electrostatic discharges may be too low to be felt by humans (less than static 3500 volts), and still damage ESDS components.

Typical static voltage generation is included in Table 3-2.

3.1.3 EOS/ESD Prevention – Warning Labels

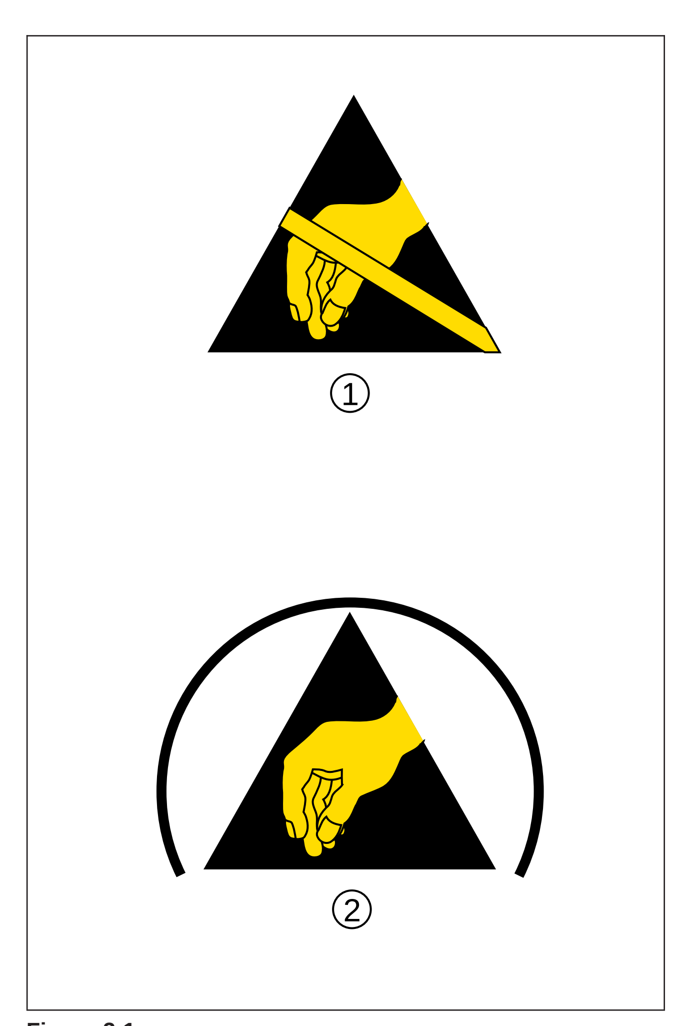


Figure 3-1
1. ESD Susceptibility Symbol
2. ESD Protective Symbol

Warning labels are available for posting in facilities and placement on devices, assemblies, equipment and packages to alert people to the possibility of inflicting electrostatic or electrical overstress damage to the devices they are handling. Examples of frequently encountered labels are shown in Figure 3-1.

Symbol (1) ESD susceptibility symbol is a triangle with a reaching hand and a slash across it. This is used to indicate that an electrical or electronic device or assembly is susceptible to damage from an ESD event.

Symbol (2) ESD protective symbol differs from the ESD susceptibility symbol in that it has an arc around the outside of the triangle and no slash across the hand. This is used to identify items that are specifically designed to provide ESD protection for ESD sensitive assemblies and devices.

Symbols (1) and (2) identify devices or an assembly as containing devices that are ESD sensitive, and that they must be handled accordingly. These symbols are promoted by the ESD association and are described in EOS/ESD standard S8.1 as well as the Electronic Industries Association (EIA) in EIA-471, IEC/TS 61340-5-1, and other standards.

Note that the absence of a symbol does not necessarily mean that the assembly is not ESD sensitive. ***When doubt exists about the sensitivity of an assembly, it must be handled as a sensitive device until it is determined otherwise.***

3.1.4 EOS/ESD Prevention – Protective Materials

ESDS components and assemblies must be protected from static sources when not being worked on in static safe environments or workstations. This protection could be conductive static-shielding boxes, protective caps, bags or wraps.

ESDS items must be removed from their protective enclosures only at static safe workstations.

It is important to understand the difference between the three types of protective enclosure material: (1) static shielding (or barrier packaging), (2) antistatic, and (3) static dissipative materials.

Static shielding packaging will prevent an electrostatic discharge from passing through the package and into the assembly causing damage.

Antistatic (low charging) packaging materials are used to provide inexpensive cushioning and intermediate packaging for ESDS items. Antistatic materials do not generate charges when motion is applied. However, if an electrostatic discharge occurs, it could pass through the packaging and into the part or assembly, causing EOS/ESD damage to ESDS components.

Static dissipative materials have enough conductivity to allow applied charges to dissipate over the surface relieving hot spots of energy. Parts leaving an EOS/ESD protected work area must be overpacked in static shielding materials, which normally also have static dissipative and antistatic materials inside.

Do not be misled by the ''color'' of packaging materials. It is widely assumed that ''black'' packaging is static shielding or conductive and that ''pink'' packaging is antistatic in nature. While that may be generally true, it can be misleading. In addition, there are many clear materials now on the market that may be antistatic and even static shielding. At one time, it could be assumed that clear packing materials introduced into the manufacturing operation would represent an EOS/ESD hazard. This is not necessarily the case now.

Caution:

Some static shielding and antistatic materials and some topical antistatic solutions may affect the solderability of assemblies, components, and materials in process. Care needs to be taken to select only packaging and handling materials that will not contaminate the assembly and use them with regard for the vendor's instructions. Solvent cleaning of static dissipative or antistatic surfaces can degrade their ESD performance. Follow the manufacturer's recommendations for cleaning.

3.2 EOS/ESD Safe Workstation/EPA

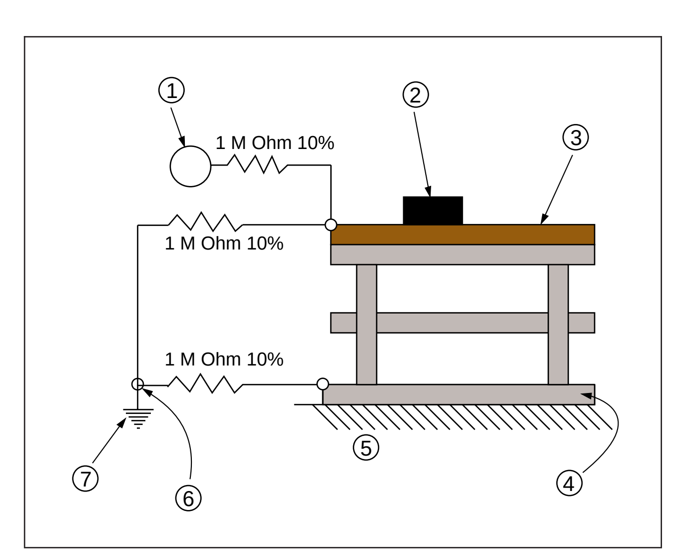


Figure 3-2 Series Connected Wrist Strap

1. **Personal wrist strap**
2. **EOS protective trays, shunts, etc.**
3. **EOS protective table top**
4. **EOS protective floor or mat**
5. **Building floor**
6. **Common ground point**
7. **Ground**

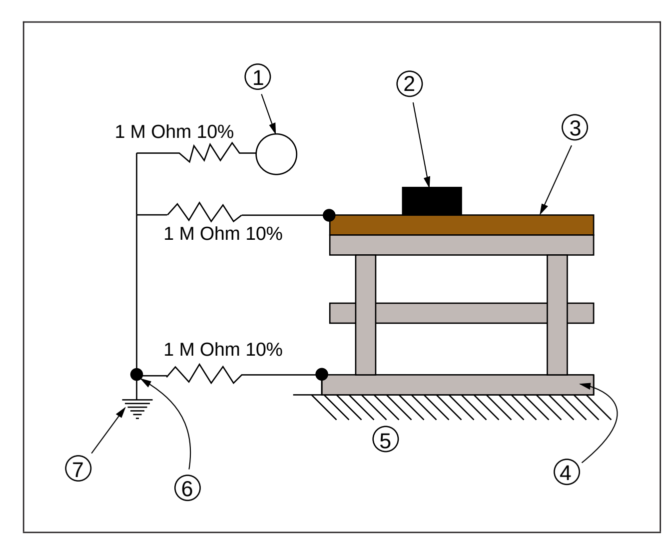


Figure 3-3 Parallel Connected Wrist Strap

1. **Personal wrist strap**
2. **EOS protective trays, shunts, etc.**
3. **EOS protective table top**
4. **EOS protective floor or mat**
5. **Building floor**
6. **Common ground point**
7. **Ground**

An EOS/ESD safe workstation prevents damage to sensitive components from spikes and static discharges while operations are being performed. Safe workstations should include EOS damage prevention by avoiding spike generating repair, manufacturing or testing equipment. Soldering irons, solder extractors and testing instruments can generate energy of sufficient levels to destroy extremely sensitive components and seriously degrade others.

For ESD protection, a path-to-ground must be provided to neutralize static charges that might otherwise discharge to a device or assembly. ESD safe workstations/EPAs also have static dissipative or antistatic work surfaces that are connected to a common ground. Provisions are also made for grounding the worker's skin, preferably via a wrist strap to eliminate charges generated on the skin or clothing.

Provision must be made in the grounding system to protect the worker from live circuitry as the result of carelessness or equipment failure. This is commonly accomplished through resistance in line with the ground path, which also slows the charge decay time to prevent sparks or surges of energy from ESD sources. Additionally, a survey must be performed of the available voltage sources that could be encountered at the workstation to provide adequate protection from personnel electrical hazards.

For maximum allowable resistance and discharge times for static safe operations, see Table 3-3.

Table 3-3 Maximum Allowable Resistance and Discharge Times for Static Safe Operations

Reading from Operator Through	Maximum Tolerable Resistance	Maximum Acceptable Discharge Time
Floor mat to ground	1000 megohms	less than 1 sec.
Table mat to ground	1000 megohms	less than 1 sec.
Wrist strap to ground	100 megohms	less than 0.1 sec.

Note: The selection of resistance values is to be based on the available voltages at the station to ensure personnel safety as well as to provide adequate decay or discharge time for ESD potentials.

Examples of acceptable workstations are shown in Figures 3-2 and 3-3. When necessary, air ionizers may be required for more sensitive applications. The selection, location, and use procedures for ionizers must be followed to ensure their effectiveness.

3.2 EOS/ESD Safe Workstation/EPA (cont.)

Keep workstation(s) free of static generating materials such as Styrofoam, plastic solder removers, sheet protectors, plastic or paper notebook folders, and employees' personal items.

Periodically check workstations/EPAs to make sure they work. EOS/ESD assembly and personnel hazards can be caused by improper grounding methods or by an oxide build-up on grounding connectors. Tools and equipment must be periodically checked and maintained to ensure proper operation.

Note: Because of the unique conditions of each facility, particular care must be given to ''third wire'' ground terminations.

Frequently, instead of being at workbench or earth potential, the third wire ground may have a ''floating'' potential of 80 to 100 volts. This 80 to 100 volt potential between an electronic assembly on a properly grounded EOS/ESD workstation/EPA and a third wire grounded electrical tool may damage EOS sensitive components or could cause injury to personnel. Most ESD specifications also require these potentials to be electrically common. The use of ground fault interrupter (GFI) electrical outlets at EOS/ESD workstations/EPAs is highly recommended.

3.3 Handling Considerations

3.3.1 Handling Considerations – Guidelines

Avoid contaminating solderable surfaces prior to soldering. Whatever comes in contact with these surfaces must be clean. When boards are removed from their protective wrappings, handle them with great care. Touch only the edges away from any edge connector tabs. Where a firm grip on the board is required due to any mechanical assembly procedure, gloves meeting EOS/ESD requirements need to be worn. These principles are especially critical when no-clean processes are employed.

Care must be taken during assembly and acceptability inspections to ensure product integrity at all times. Table 3-4 provides general guidance.

Moisture sensitive components (as classified by IPC/JEDEC J-STD-020 or equivalent documented procedure) must be handled in a manner consistent with IPC/JEDEC J-STD-033 or an equivalent documented procedure.

Table 3-4 Recommended Practices for Handling Electronic Assemblies

1. Keep workstations clean and neat. There must not be any eating, drinking, or use of tobacco products in the work area.
2. Minimize the handling of electronic assemblies and components to prevent damage.
3 When gloves are used, they need to be changed as frequently as necessary to prevent contamination from dirty gloves.
4. Solderable surfaces are not to be handled with bare hands or fingers. Body oils and salts reduce solderability, promote corrosion and dendritic growth. They can also cause poor adhesion of subsequent coatings or encapsulates.
5. Do not use hand creams or lotions containing silicone since they can cause solderability and conformal coating adhesion problems.
6. Never stack electronic assemblies or physical damage may occur. Special racks need to be provided in assembly areas for temporary storage.
7. Always assume the items are ESDS even if they are not marked.
8. Personnel must be trained and follow appropriate ESD practices and procedures.
9. Never transport ESDS devices unless proper packaging is applied.

3.3.2 Handling Considerations – Physical Damage

Improper handling can readily damage components and assemblies (e.g., cracked, chipped or broken components and connectors, bent or broken terminals, badly scratched board surfaces and conductor lands). Physical damage of this type can ruin the entire assembly or attached components.

3.3.3 Handling Considerations – Contamination

Many times product is contaminated during the manufacturing process due to careless or poor handling practices causing soldering and coating problems; body salts and oils, and unauthorized hand creams are typical contaminants. Body oils and acids can reduce solderability, promote corrosion and dendritic growth. They can also cause poor adhesion of subsequent coatings or encapsulants. Normal cleaning procedures may not remove all contaminants. Therefore it is important to minimize the opportunities for contamination. The best solution is prevention. *Frequently washing ones hands and handling boards only by the edges without touching the lands or pads will aid in reducing contamination. When required the use of pallets and carriers will also aid in reducing contamination during processing.*

The use of gloves or finger cots many times creates a false sense of protection and within a short time can become more contaminated than bare hands. When gloves or finger cots are used they should be discarded and replaced often. Gloves and finger cots need to be carefully chosen and properly utilized.

3.3.4 Handling Considerations – Electronic Assemblies

Even if no ESDS markings are on an assembly, it still needs to be handled as if it were an ESDS assembly. However, ESDS components and electronic assemblies need to be identified by suitable EOS/ESD labels (see Figure 3-1). Many sensitive assemblies will also be marked on the assembly itself, usually on an edge connector. To prevent ESD and EOS damage to sensitive components, all handling, unpacking, assembly and testing must be performed at a static controlled workstation (see Figures 3-2 and 3-3).

3.3.5 Handling Considerations – After Soldering

After soldering and cleaning operations, the handling of electronic assemblies still requires great care. Fingerprints are extremely hard to remove and will often show up in conformally coated boards after humidity or environmental testing. Gloves or other protective handling devices need to be used to prevent such contamination. Use mechanical racking or baskets with full ESD protection when handling during cleaning operations.

3.3.6 Handling Considerations – Gloves and Finger Cots

The use of gloves or finger cots may be required under contract to prevent contamination of parts and assemblies. Gloves and finger cots must be carefully chosen to maintain EOS/ESD protection.

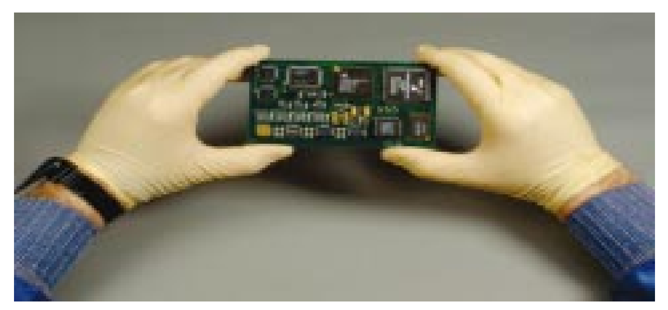


Figure 3-4

Figure 3-4 and 3-5 provide examples of:

- Handling with clean gloves and full EOS/ESD protection.
- Handling during cleaning procedures using solvent resistant gloves meeting all EOS/ESD requirements.
- Handling with clean hands by board edges using full EOS/ESD protection.

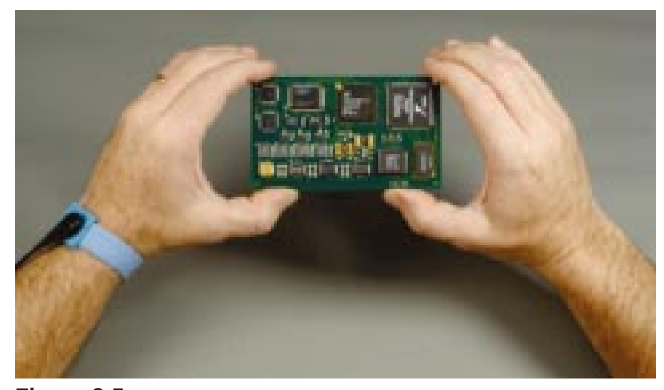


Figure 3-5

Note: Any assembly related component if handled without EOS/ESD protection may damage electrostatic sensitive components. This damage could be in the form of latent failures, or product degradation not detectable during initial test or catastrophic failures found at initial test.

4 Hardware

This section illustrates several types of hardware used to mount electronic devices to a printed circuit assembly (PCA) or any other types of assemblies requiring the use of any of the following: screws, bolts, nuts, washers, fasteners, clips, component studs, tie downs, rivets, connector pins, etc. This section is primarily concerned with visual assessment of proper securing (tightness), and also with damage to the devices, hardware, and the mounting surface that can result from hardware mounting.

Compliance to torque requirements is to be verified as specified by customer documentation. The verification procedure ensures that no damage to components or assembly occurs. Where torque requirements are not specified, follow standard industry practices.

Process documentation (drawings, prints, parts list, build process) will specify what to use; deviations need to have prior customer approval.

Note: Criteria in this section do not apply to attachments with self-tapping screws.

Visual inspection is performed in order to verify the following conditions:

a. Correct parts and hardware.
b. Correct sequence of assembly.
c. Correct security and tightness of parts and hardware.
d. No discernible damage.
e. Correct orientation of parts and hardware.

The following topics are addressed in this section:

4.1 Hardware Installation

4.1.1 Hardware Installation – Electrical Clearance

Also see 1.4.5.

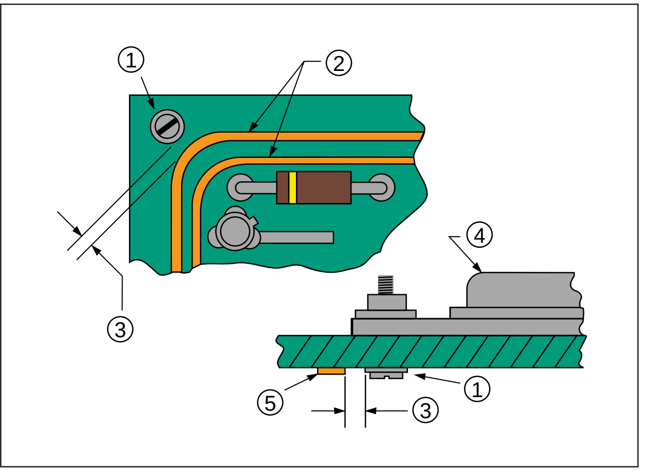


Figure 4-1

1. **Metallic hardware**
2. **Conductive pattern**
3. **Specified minimum electrical clearance**
4. **Mounted component**
5. **Conductor**

Acceptable - Class 1,2,3

- Spacing between noncommon conductors does not violate specified minimum electrical clearance (3). This is shown in Figure 4-1 as the distances between (1) & (2) and (1) & (5).

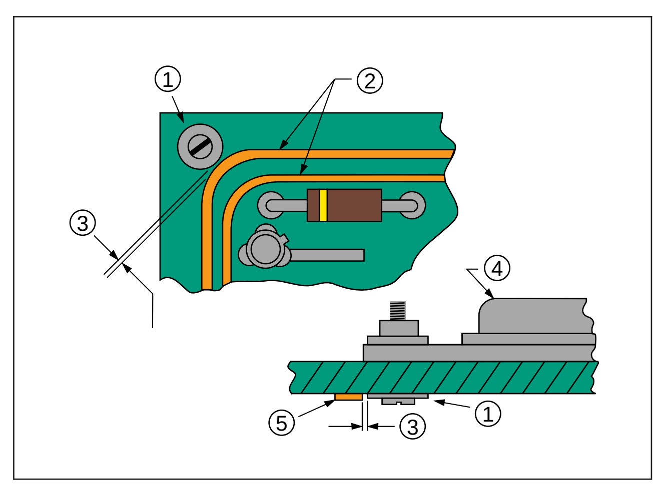


Figure 4-2

1. **Metallic hardware**
2. **Conductive pattern**
3. **Spacing less than electrical clearance requirements**
4. **Mounted component**
5. **Conductor**

Defect - Class 1,2,3

- Hardware reduces spacing to less than specified minimum electrical clearance.

4.1.2 Hardware Installation – Interference

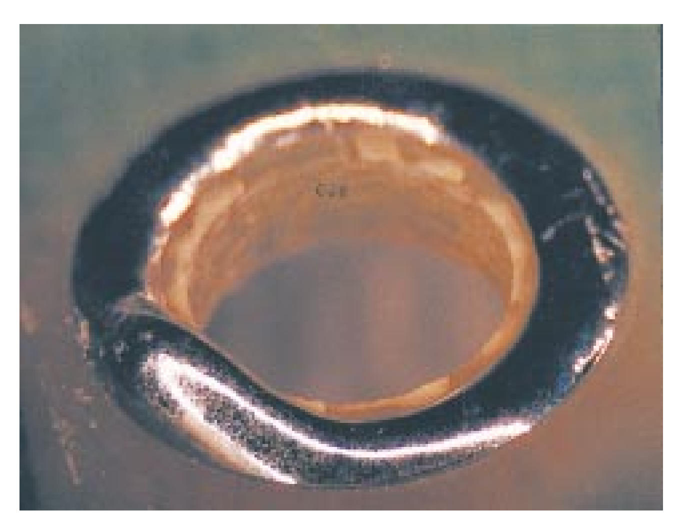


Figure 4-3

Acceptable - Class 1,2,3

- Mounting area clear of obstructions to assembly requirements.

Defect - Class 1,2,3

- Excess solder (uneven) on mounting holes where mechanical assembly will be affected.
- Anything that interferes with mounting of required hardware.

4.1.3 Hardware Installation – Threaded Fasteners

A minimum of one and one half threads need to extend beyond the threaded hardware, (e.g., nut) unless otherwise specified by engineering drawing. Bolts or screws may be flush with the end of the threaded hardware only where threads could interfere with other components or wires and when locking mechanisms are used.

Thread extension should not be more than 3 mm [0.12 in] plus one and one-half threads for bolts or screws up to 25 mm [0.984 in] long or more than 6.3 mm [0.248 in] plus one and one-half threads for bolts or screws over 25 mm [0.984 in]. This is providing that the extension does not interfere with any adjacent part and that the designed electrical clearance requirements are met.

4.1.3 Hardware Installation – Threaded Fasteners (cont.)

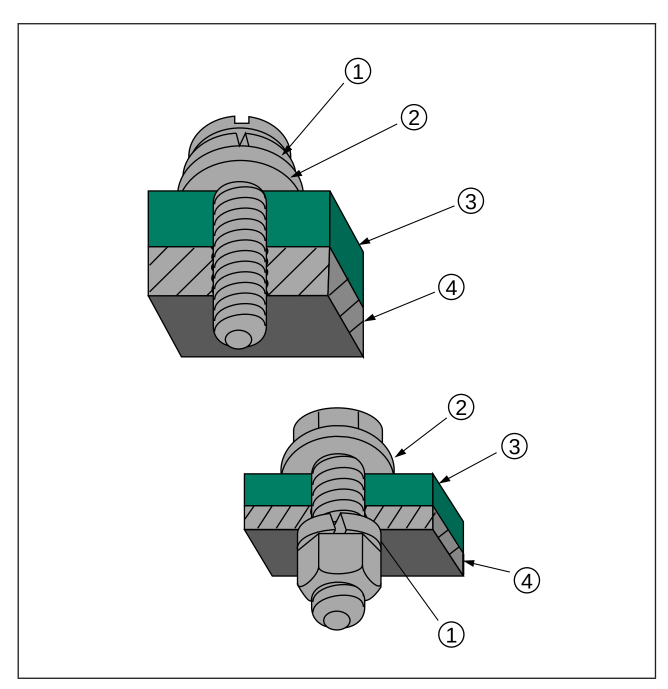


Figure 4-4
1. Lock washer
2. Flat washer
3. Nonconductive material (laminate, etc.)
4. Metal (not conductive pattern or foil)

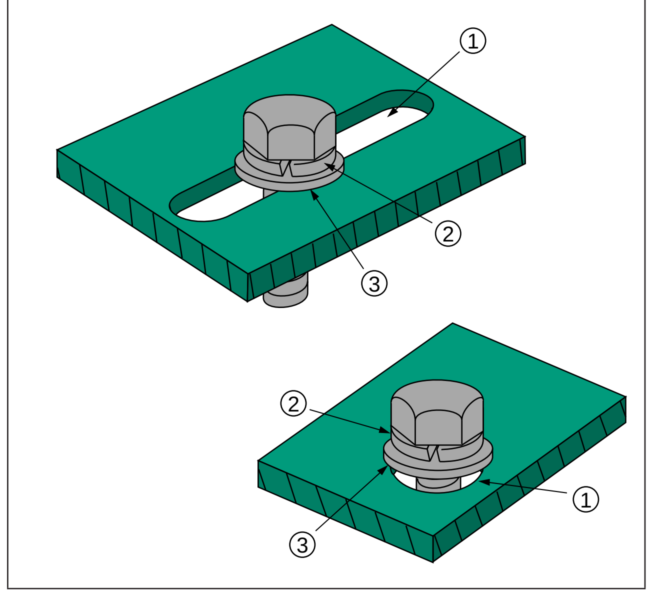


Figure 4-5
1. Slot or hole
2. Lock washer
3. Flat washer

Acceptable - Class 1,2,3

- Proper hardware sequence.
- Slot is covered with flat washer, Figure 4-5.
- Hole is covered with flat washer, Figure 4-5.

Acceptable - Class 1
Defect - Class 2,3

- Less than one and one-half threads extend beyond the threaded hardware, (e.g., nut) unless thread extension would interfere with other component.
- Thread extension more than 3 mm [0.12 in] plus one and one-half threads for bolts or screws up to 25 mm [0.984 in].
- Thread extension more than 6.3 mm [0.248 in] plus one and one-half threads for bolts or screws over 25 mm [0.984 in].
- Bolts or screws without locking mechanisms extend less than one and one half threads beyond the threaded hardware.

4.1.3 Hardware Installation – Threaded Fasteners (cont.)

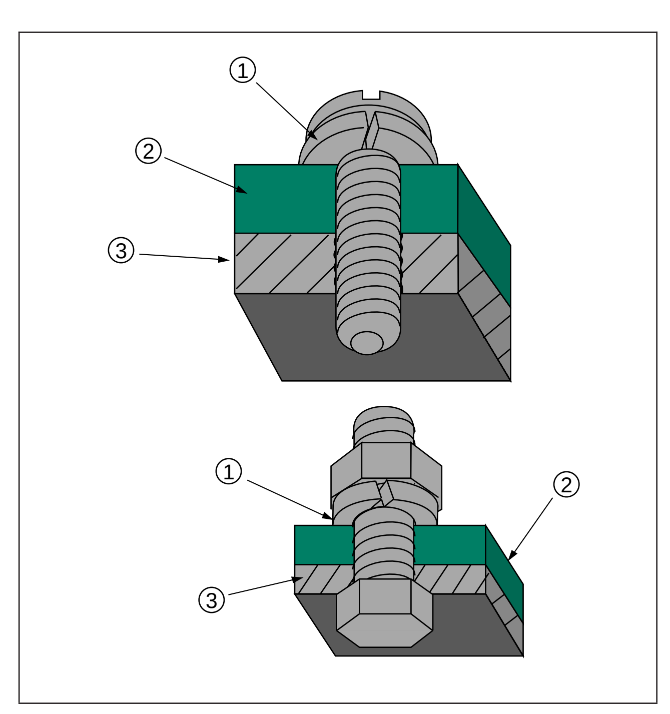


Figure 4-6

1. Lock washer
2. Nonmetal
3. Metal (not conductive pattern or foil)

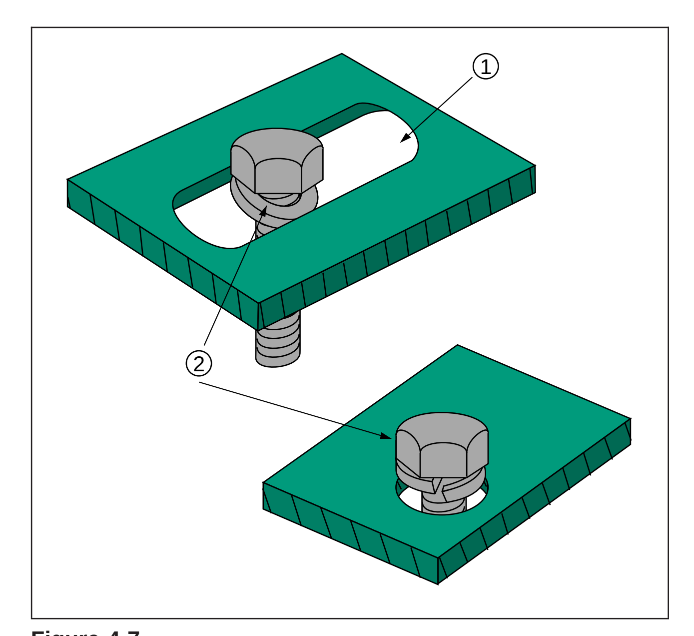


Figure 4-7

1. Slot or hole
2. Lock washer

Defect - Class 1,2,3

- Thread extension interferes with adjacent component.
- Hardware material or sequence not in conformance with drawing.
- Lock washer against nonmetal/laminate.
- Flat washer missing, Figure 4-6.
- Hardware missing or improperly installed, Figure 4-7.

4.1.3.1 Hardware Installation – Threaded Fasteners – Torque

When connections are made using threaded fasteners they must be tight to ensure the reliability of the connection. When split-ring type lock washers are used, the threaded fastener must be tight enough to compress the lock washer. Fastener torque value, if specified, is within limits.

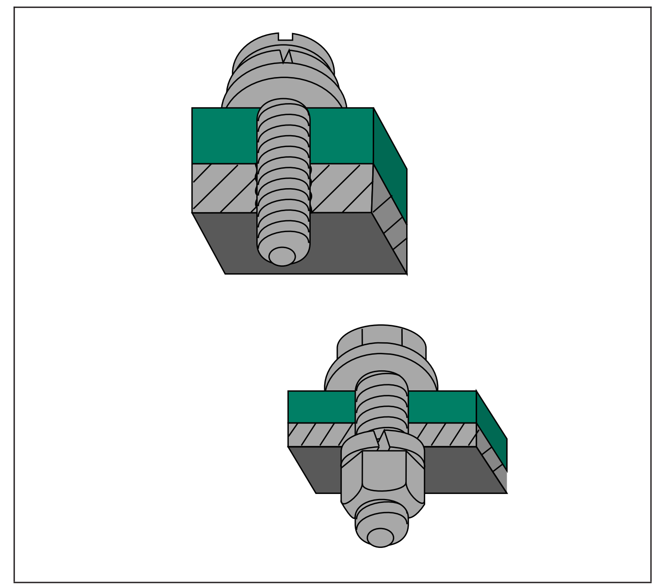


Figure 4-8

Acceptable - Class 1,2,3

- Fasteners are tight and split-ring lock washers, when used, are fully compressed.



Figure 4-9

Defect - Class 1,2,3

- Lock washer not compressed.

4.1.3.2 Hardware Installation – Threaded Fasteners – Wires

When the use of terminal lugs is not required, wires are wrapped around screw type terminals in a manner that precludes loosening when the screw is tightened, and the ends of the wire are kept short to preclude shorting to ground or other current carrying conductors.

If a washer is used, the wire/lead is to be mounted under the washer.

Unless otherwise noted, all requirements apply to both stranded and solid wires.

Special hardware staking/securing criteria may be required.



Figure 4-10

Target - Class 1,2,3

- Original lay of the strands is not disturbed (stranded wire).
- Wire wrapped a minimum of 270° around the screw body.
- Wire end secured under screw head.
- Wire wrapped in the correct direction.
- All strands are under screw head.

4.1.3.2 Hardware Installation – Threaded Fasteners – Wires (cont.)

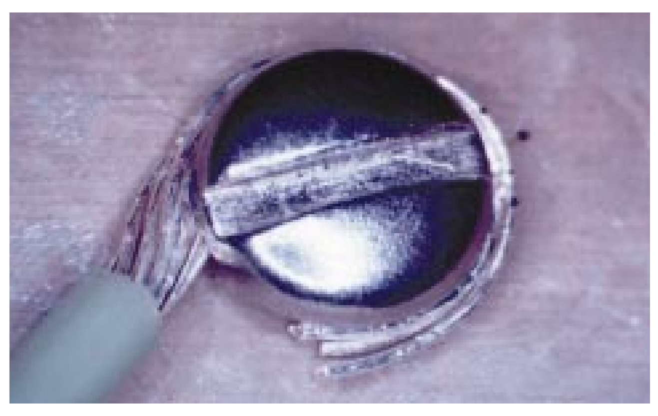


Figure 4-11



Figure 4-12

Acceptable - Class 1,2,3

- Wire wrapped around the screw body in the correct direction, but a few strands have unraveled in tightening the screw.
- Less than 1/3 of the wire diameter protrudes from under the screw head.
- Wire extending outside the screw head does not violate minimum electrical clearance.
- Mechanical attachment of the wire is in contact between the screw head and the contact surface for a minimum of 180° around the screw head.
- No insulation in the contact area.
- Wire does not overlap itself.

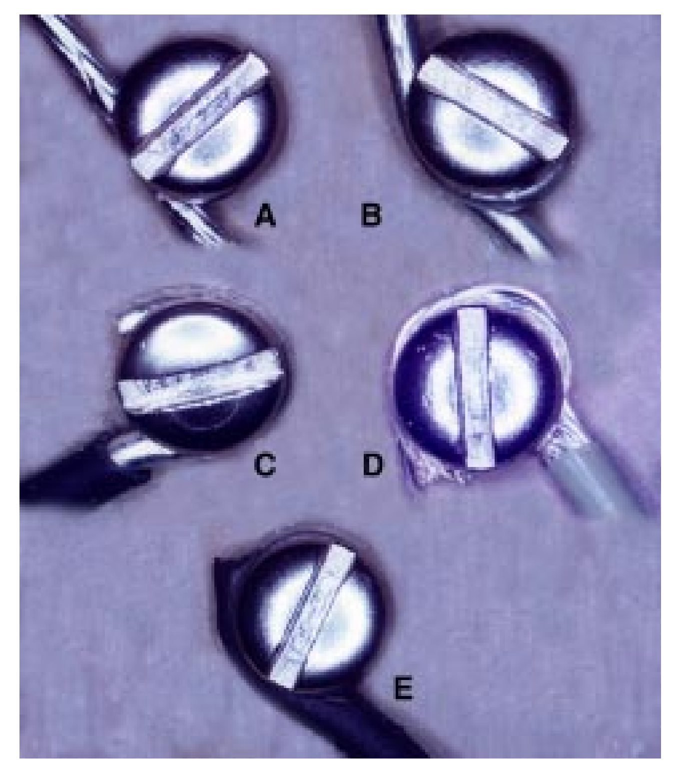


Figure 4-13

Defect - Class 1,2,3

- Wire not wrapped around screw body (A).
- Wire is overlapped (B).
- Solid wire wrapped in wrong direction (C).
- Stranded wire wrapped in wrong direction (tightening the screw unwinds the twisted wire) (D).
- Insulation in the contact area (E).
- Stranded wire is tinned (not shown).
- Missing solder or adhesive as required per customer requirements (not shown).

4.2 Connectors, Handles, Extractors, Latches

This section shows some of the many different types of hardware mounted devices, e.g., connectors, handles, extractors and plastic molded parts. These devices need to be visually inspected for cracks and damage.

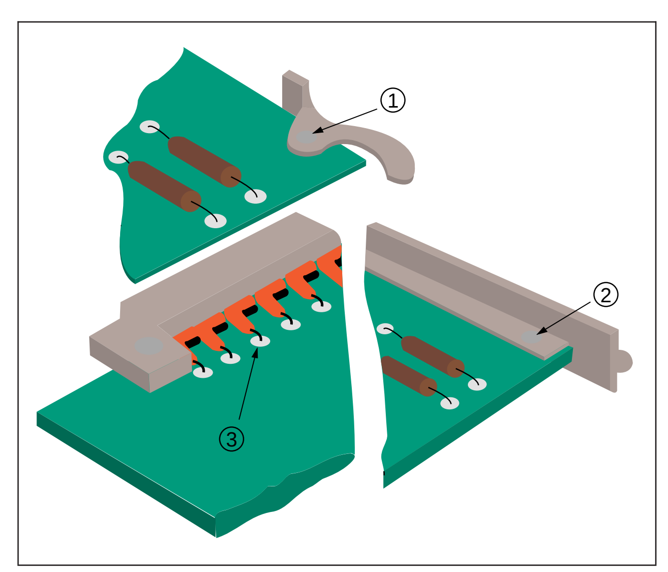


Figure 4-14
1. Extractor
2. Securing hardware
3. Component lead

Target - Class 1,2,3

- No damage to part, printed board or securing hardware (rivets, screws, etc.).

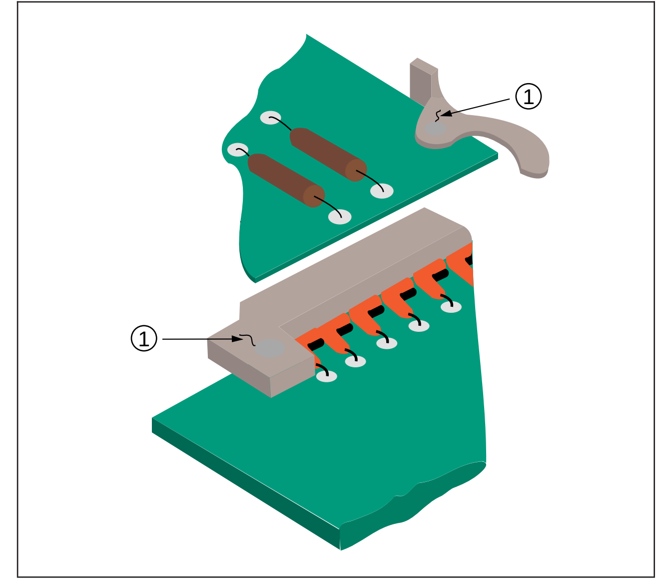


Figure 4-15
1. Crack

Acceptable - Class 1

- Cracks in the mounted part extend no more than 50% of the distance between a mounting hole and a formed edge.

Defect - Class 1

- Cracks in the mounted part extend more than 50% of the distance between a mounting hole and a formed edge.

Defect - Class 2,3

- Cracks in mounting part.

Defect - Class 1,2,3

- Crack connects a mounting hole to an edge.
- Damage/stress to connector lead pins.

4.3 Connector Pins

This section covers two types of pin installations; edge connector pins and connector pins. Installation of these devices is usually done with automated equipment. Visual inspection of this mechanical operation includes: correct pins, damaged pins, bent and broken pins, damaged spring contacts and damage to the substrate or conductive pattern. For connector mounting criteria see 7.1.8. For connector damage criteria see 9.5.

4.3.1 Connector Pins – Edge Connector Pins

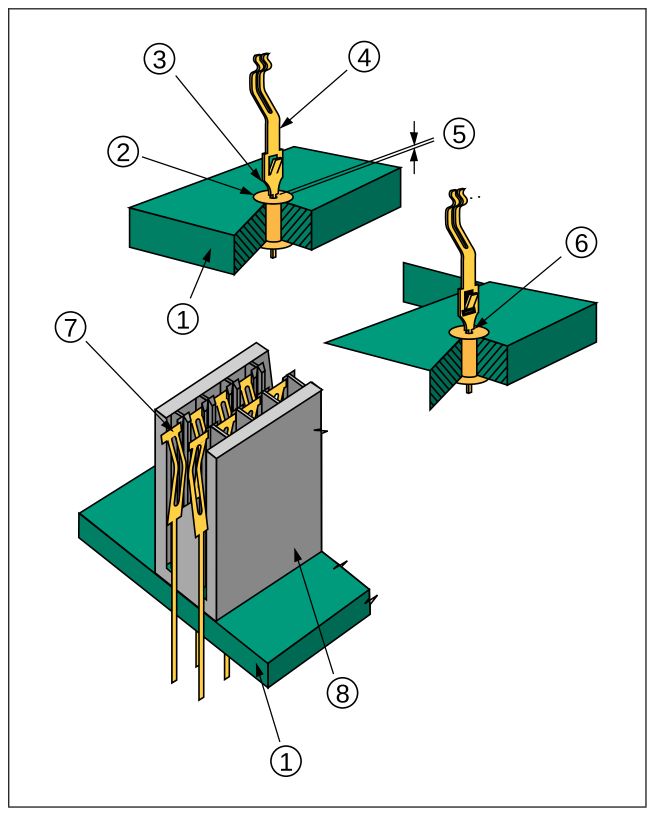


Figure 4-16
1. Backplane
2. Land
3. Shoulder
4. Contact
5. Gap
6. No land damage
7. No discernible damage
8. Insulator

Acceptable - Class 1,2,3

- Contact is not broken or twisted. Gap is within specified tolerance.
- No land damage.
- Contact is contained within the insulator.

Note: To provide allowance for an extraction tool, the gap between the contact shoulder and the land needs to be adequate for each manufacturer's repair tooling.

4.3.1 Connector Pins – Edge Connector Pins (cont.)

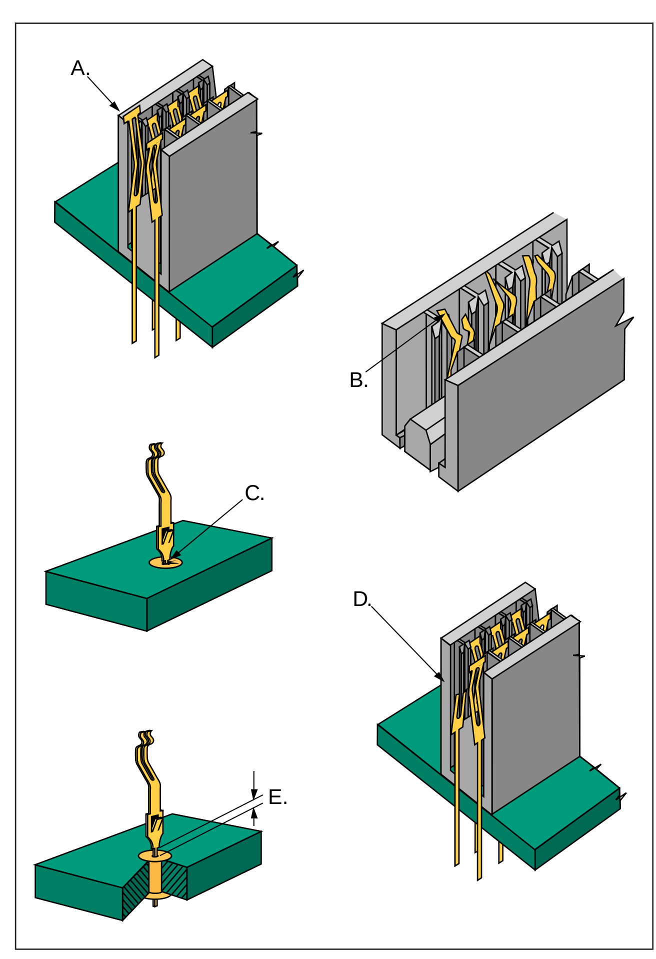


Figure 4-17

Defect - Class 1,2,3

- Contact is above insulator (A).
- Contacts are twisted or otherwise deformed (B).
- Land is damaged (C).
- Contact is broken (D).
- Gap between contact shoulder and land is greater than specified (E).

4.3.2 Connector Pins – Press Fit Pins

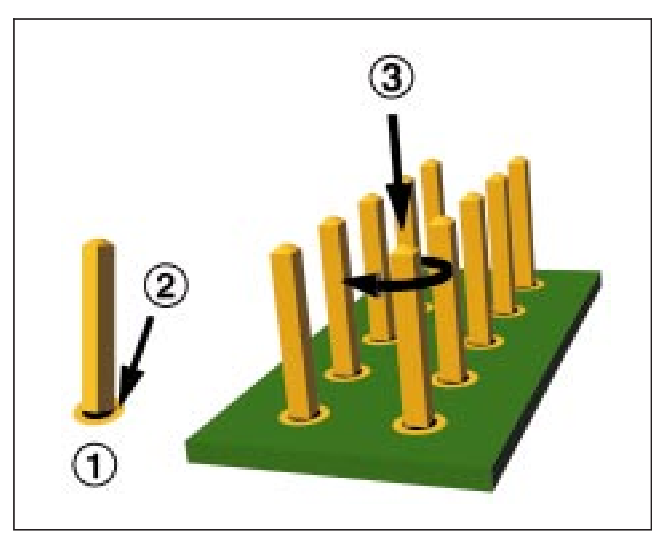


Figure 4-18
1. No discernible damage
2. Land
3. No discernible twist

Target - Class 1,2,3

- Pins are straight, not twisted and properly seated.
- No discernible damage.

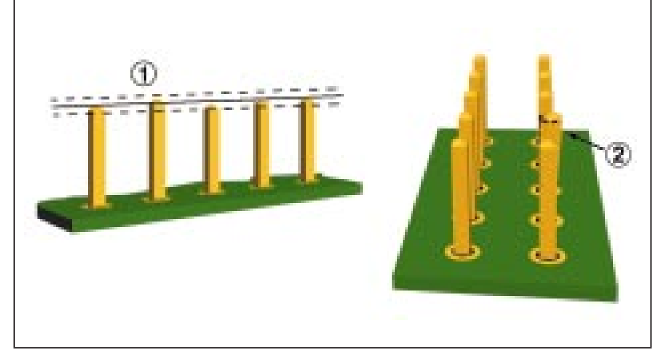


Figure 4-19
1. Pin height tolerance
2. Less than 50% pin thickness

Acceptable - Class 1,2,3

- Pins are slightly bent off center by 50% pin thickness or less.
- Pin height varies within tolerance.

Note: Nominal height tolerance is per pin connector or master drawing specification. The connector pins and mating connector must have a good electrical contact.

4.3.2 Connector Pins – Press Fit Pins (cont.)

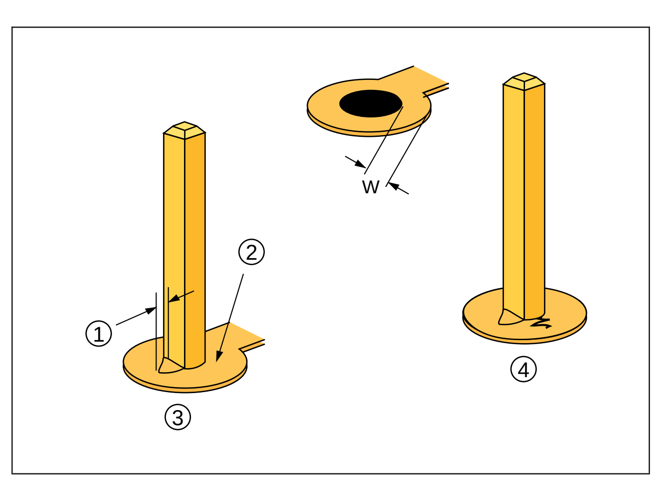


Figure 4-20

1. **Land lifted 75% of annular ring or less**
2. **Land with conductor**
3. **Land not fractured**
4. **Land lifted, fractured but firmly attached land without conductor (nonfunctional)**

Acceptable - Class 1,2

- Less than or equal to 75% of the width (W) of the annular ring is lifted.
- Damaged nonfunctional lands for single and double-sided boards are acceptable if firmly attached to board in unlifted areas.

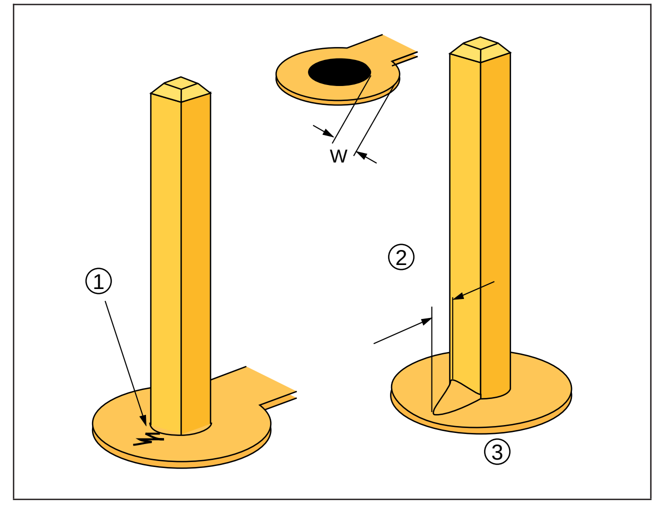


Figure 4-21

1. **Land fractured**
2. **Functional land lifted greater than 75% of annular ring width**
3. **Land lifted**

Defect - Class 1,2

- Any functional annular ring which is lifted more than 75% of the width (W).

Defect - Class 3

- Any lifted or fractured annular rings with press fit pins.

Note: For additional information see 10.2.9.2 Conductor/Land Damage - Lifted Pads/Lands.

4.3.2 Connector Pins – Press Fit Pins (cont.)

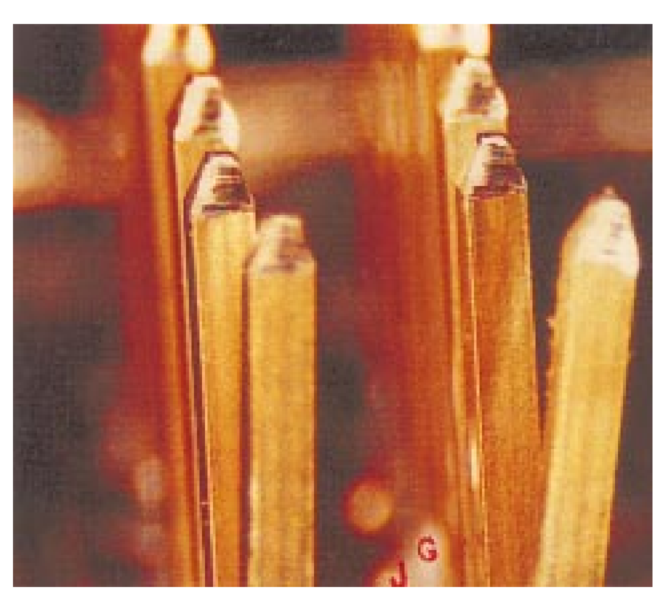


Figure 4-22

Defect - Class 1,2,3

- Pin is bent out of alignment. (Pin is bent off center greater than 50% pin thickness.)

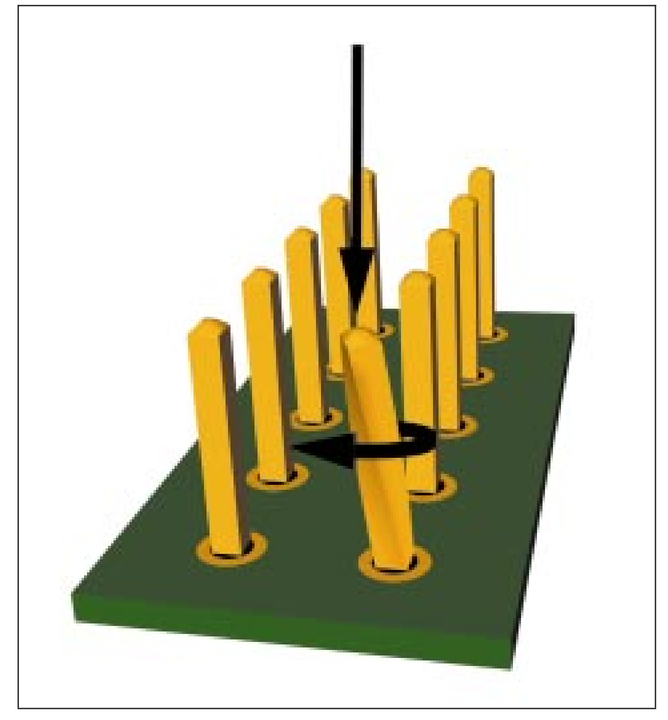


Figure 4-23

Defect - Class 1,2,3

- Pin visibly twisted.

4.3.2 Connector Pins – Press Fit Pins (cont.)

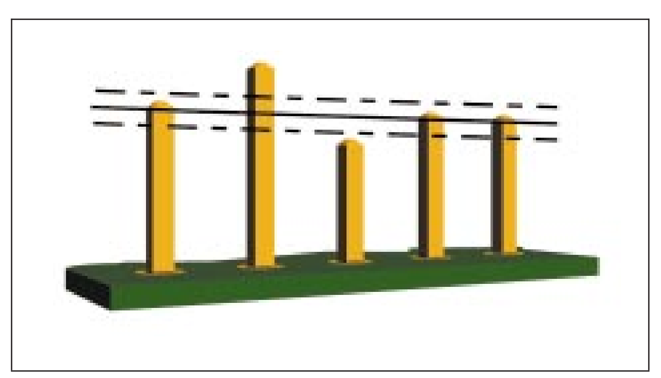


Figure 4-24

Defect - Class 1,2,3

- Pin height is out of tolerance as to specification.

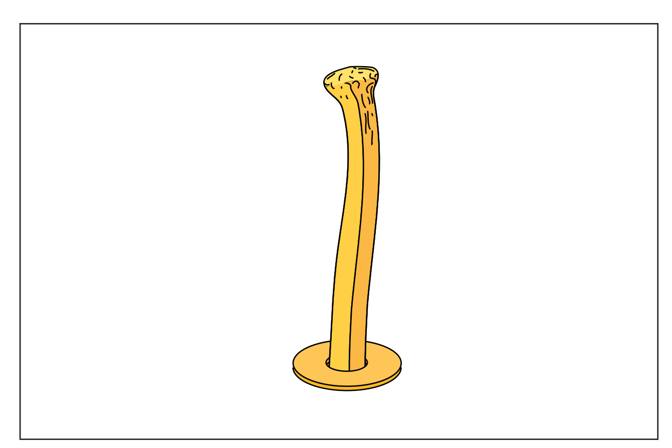


Figure 4-25

Defect - Class 1,2,3

- Damaged pin as a result of handling or insertion.
  - Mushroomed
  - Bent

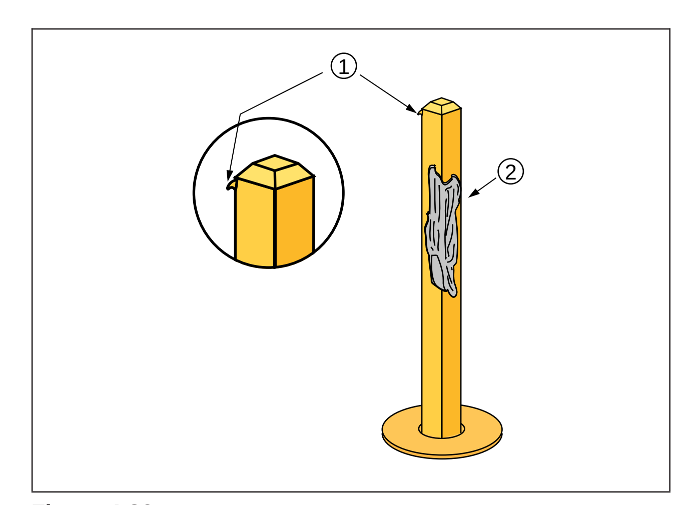


Figure 4-26
1. Burr
2. Plating missing

Defect - Class 1,2,3

- Damaged pin (exposed basis metal).

Defect - Class 2,3

- Burr

4.3.2.1 Press Fit Pins – Soldering

The term ''press fit pins'' is generic in nature and many types of pressure inserted pins, e.g. connector, staked, etc., are not intended to be soldered. If soldering is required the following criteria is applicable.

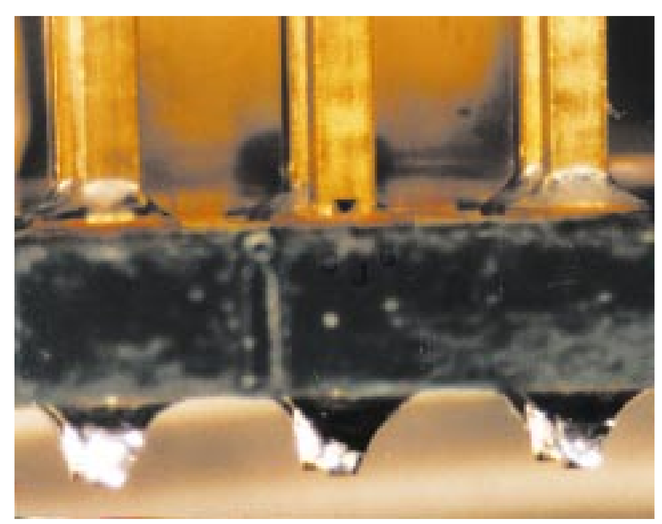


Figure 4-27

Target - Class 1,2,3

- A 360° solder fillet is evident on the secondary side of the assembly.

Note: Solder fillet or fill on primary side is not required.

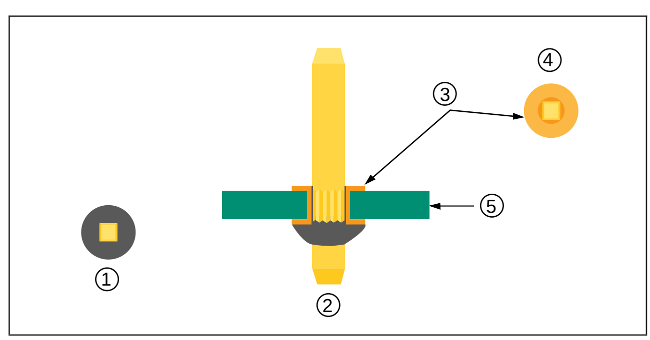


Figure 4-28
1. **Bottom view**
2. **Side view**
3. **Land**
4. **Top view**
5. **PCB**

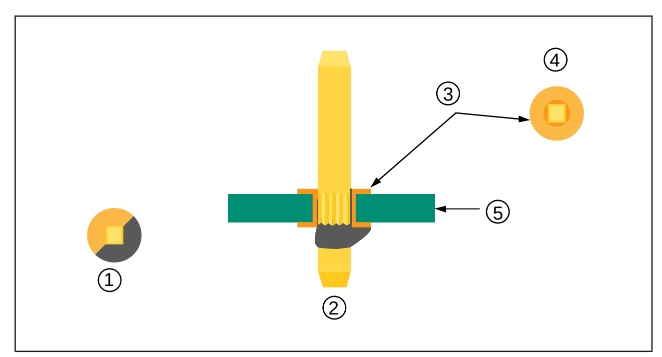


Figure 4-29
1. **Bottom view**
2. **Side view**
3. **Land**
4. **Top view**
5. **PCB**

Acceptable - Class 1,2

- Solder fillet or coverage (secondary side) is present on two adjacent sides of the pin.

4.3.2.1 Press Fit Pins – Soldering (cont.)

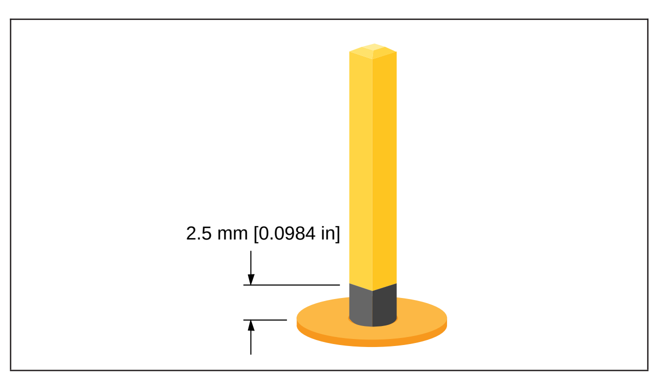


Figure 4-30

Acceptable - Class 1

- Solder wicking is permitted above 2.5 mm [0.0984 in] on sides of pins provided there is no solder build up which interferes with subsequent attachments to the pin.

Acceptable - Class 2,3

- Solder wicking on sides of pins is less than 2.5 mm [0.0984 in], provided the solder does not interfere with subsequent attachments to the pin.

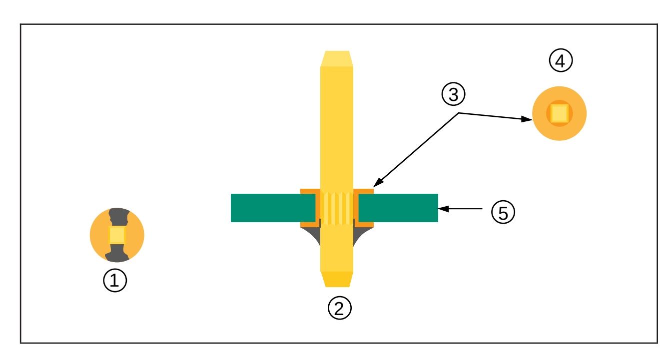


Figure 4-31
1. **Bottom view**
2. **Side view**
3. **Land**
4. **Top view**
5. **PCB**

Defect - Class 1,2

- Solder fillet or coverage is evident on less than two adjacent sides of the pin on the secondary side.

Defect - Class 3

- Solder fillet is evident on less than four sides of the pin on the secondary side.

Defect - Class 1,2,3

- Solder build up interferes with subsequent attachments to the pin.

Defect - Class 2,3

- Solder wicking exceeds 2.5 mm [0.0984 in].

4.3.3 Connector Pins – Backplanes

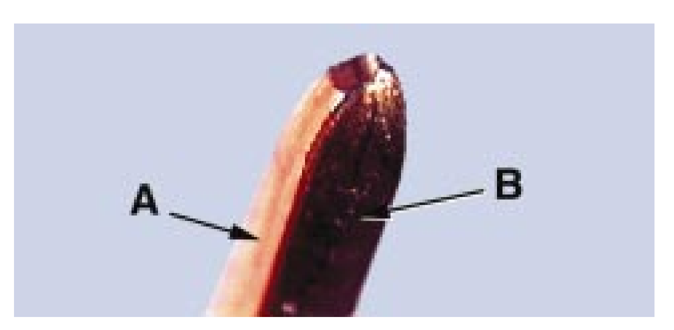


Figure 4-32
A. Sheared/nonmating surface of connector pin
B. Coined/mating surface of connector pin

Acceptable - Class 1,2,3

- Chip on nonmating surface of separable connector pin.
- Burnish on mating surface of separable connector pin, providing that plating has not been removed.
- Chip that encroaches the mating surface of separable connector pin which will not be in the mating connector contact wear path.




Figure 4-33

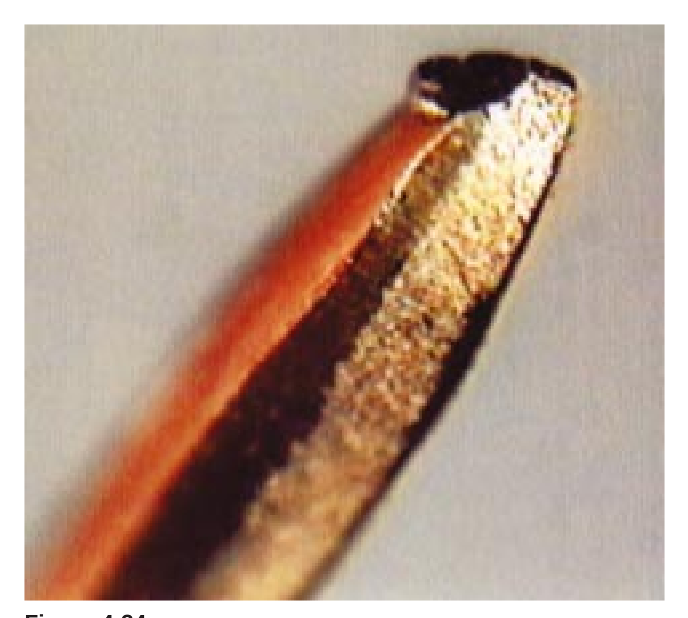


Figure 4-34

Defect - Class 1, 2, 3

- Chipped pin on mating surface of separable connector, Figure 4-33.
- Scratched pin that exposes nonprecious plating or basis metal.
- Missing plating on required areas.
- Burr on pin, Figures 4-34.
- Cracked PCB substrate.
- Pushed out barrel as indicated by copper protruding from bottom side of PCB.

4.4 Wire Bundle Securing

Additional criteria can be found in IPC/WHMA-A-620.

4.4.1 Wire Bundle Securing – General

Note: Do not subject wax impregnated lacing tape to cleaning solvents. Beeswax is unacceptable for Class 3.

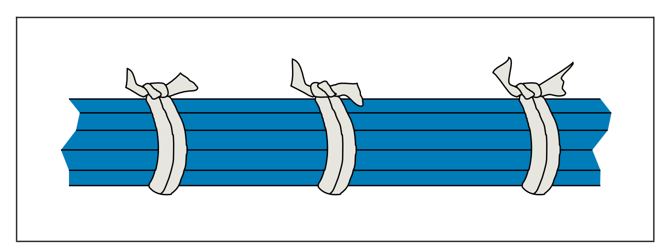


Figure 4-35

Target - Class 1,2,3

- Restraining devices are neat and tight, and spaced to keep the wires secured in a tight neat bundle.

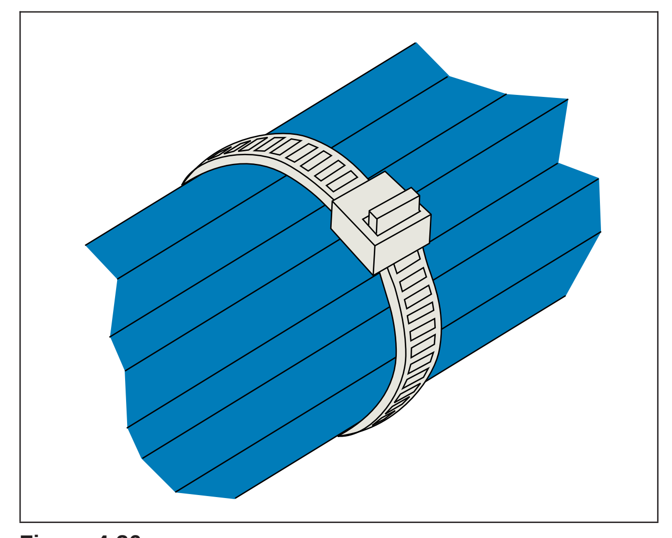


Figure 4-36

Acceptable - Class 1,2,3

- The end of the tie wrap:
  - Protrudes a maximum of one tie wrap thickness.
  - Is cut reasonably square to the face of the wrap.
- The wires are secured in the wire bundle.

4.4.1 Wire Bundle Securing – General (cont.)

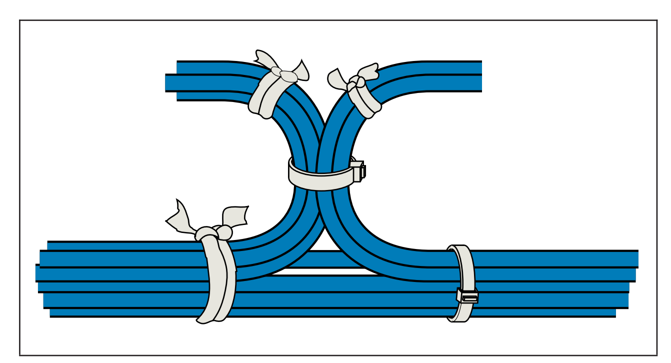


Figure 4-37

Acceptable - Class 1,2,3

- Lacing or tie wraps are placed on both sides of a wire break-out.
- Spot tie wraps are neat and tight.
- The wires are secured in the wire bundle.
- Square knot, surgeons knot or other approved knot is used to secure the lacing, Figure 4-38.

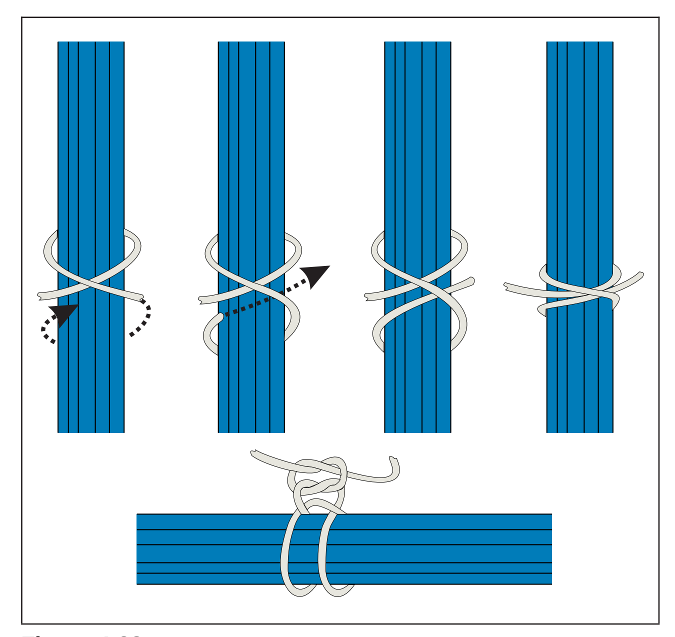


Figure 4-38

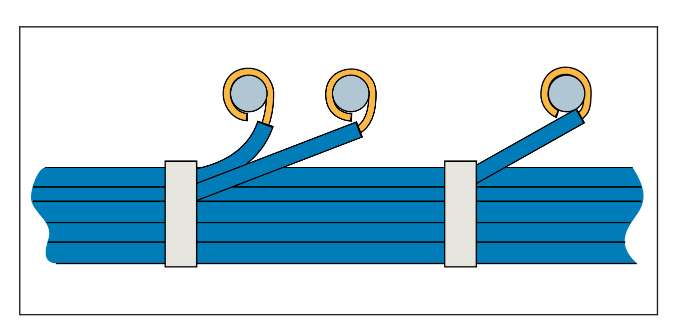


Figure 4-39

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- The wire is under stress at the wrap.

4.4.1 Wire Bundle Securing – General (cont.)

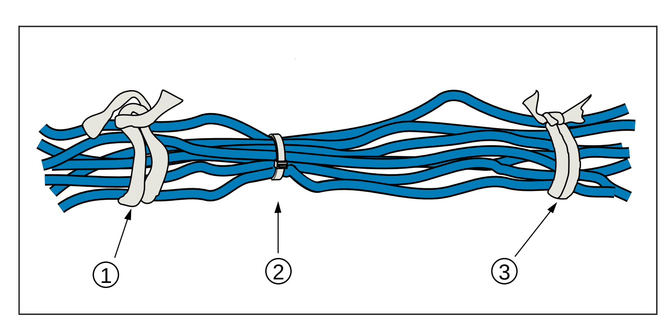


Figure 4-40

1. **Loose knot/tie**
2. **Tie wrap is too tight. Lacing or tie wrap cuts into the insulation.**
3. **Loose bundle**

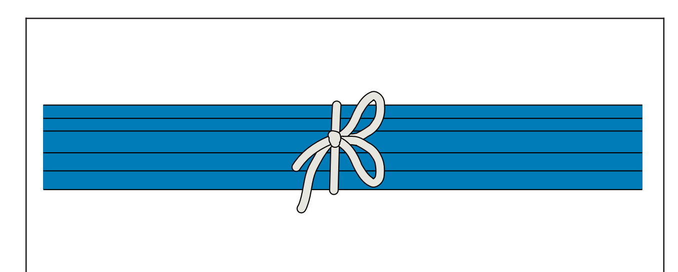


Figure 4-41

Defect - Class 1,2,3

- Spot tie wrap or knot is loose.
- Spot tie wrap cuts into the insulation.
- Wire bundle is loose.
- Cable tied with an improper knot. This tie may eventually loosen.

4.4.2 Wire Bundle Securing – Lacing

Lacing differs from cable ties because it is a continuous lace. Lacing has closer spacing than cable ties. Criteria for cable ties apply to lacing.

Note: Do not subject wax impregnated lacing tape to cleaning solvents. Beeswax is unacceptable for Class 3.

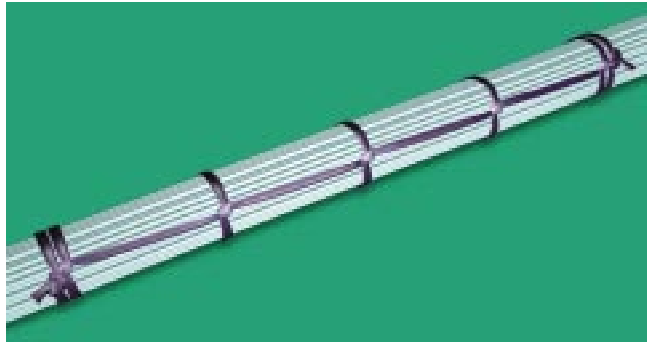


Figure 4-42

Acceptable - Class 1,2,3

- Lacing begins and ends with a locking knot.
- Lacing is tight and wires are kept secure in a neat bundle.

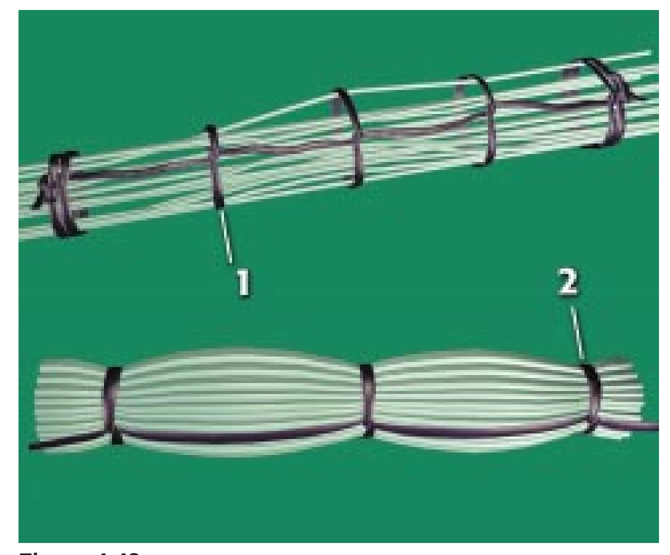


Figure 4-43

Defect - Class 1,2,3

- Lacing is loose, leaving wires loose in the wire bundle (1).
- Lacing is too tight, cutting into insulation (2).

4.4.2.1 Wire Bundle Securing – Lacing – Damage

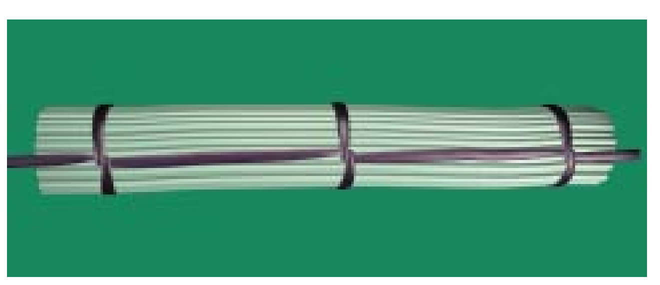


Figure 4-44

Target - Class 1,2,3

- Restraining devices are not worn, frayed, nicked, or broken in any location.
- Restraining devices do not have sharp edges that may be a hazard to personnel or equipment.

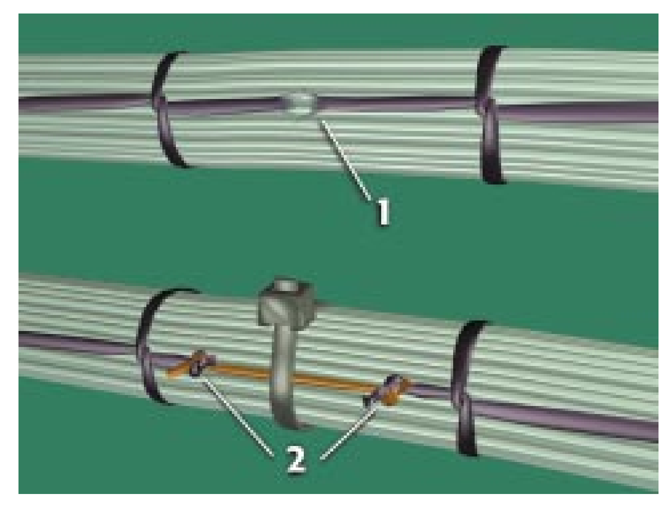


Figure 4-45

Acceptable - Class 1,2
Defect - Class 3

- Restraining devices exhibit minor fraying, nicks, or wear of less than 25% of the device thickness.

Defect - Class 1,2

- Damage or wear to restraining device greater than 25% of the device thickness (1).

Defect - Class 3

- Damage or wear to restraining device (1).

Defect - Class 1,2,3

- Broken lacing ends are not tied off using a square knot, surgeons knot, or other approved knot (2).

4.5 Routing

These criteria are applicable to single wires or wire bundles.

Wire bundles are positioned to minimize crossover and maintain a uniform appearance.

4.5.1 Routing – Wire Crossover



Figure 4-46

Target - Class 1,2,3

- Wire lay is essentially parallel to the axis of the bundle with no crossover.
- Coaxial cable secured with tie wraps/straps.

Acceptable - Class 1, 2, 3

- Wires twist and crossover, but bundle is essentially uniform in diameter.

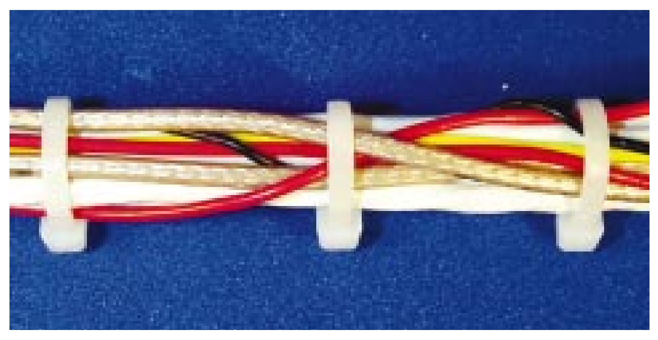


Figure 4-47

Acceptable - Class 1
Process Indicator -Class 2
Defect - Class 3

- Wires twist and crossover underneath a restraining device.

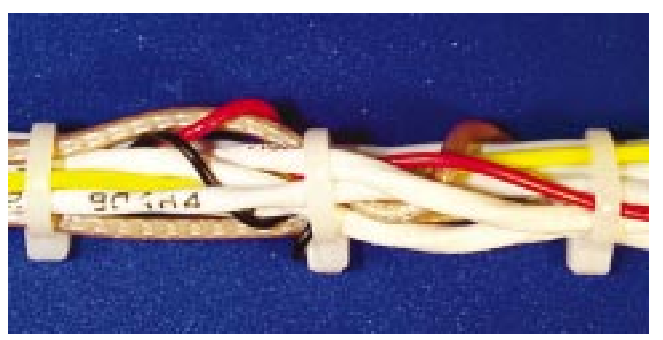


Figure 4-48

Acceptable - Class 1
Defect -Class 2,3

- Any kinks that violate minimum bend radius.
- Bundle is not uniform in diameter.
- Excessive crossover.
- Wire insulation is damaged (see 6.8.2).

4.5.2 Routing – Bend Radius

Bend radius is measured along the inside curve of the wire or wire bundles.

Table 4-1 Minimum Bend Radius Requirements

Cable Type	Class 1	Class 2	Class 3
Coaxial Fixed Cable[2]	5X OD[1]	5X OD[1]	5X OD[1]
Coaxial Flexible Cable[3]	10X OD[1]	10X OD[1]	10X OD[1]
Unshielded Wires	No Requirement Established		3X for ≤AWG 10 5X for >AWG 10
Shielded Wires and Cables	No Requirement Established		5X OD[1]
Semirigid Coax	Not less than manufacturer's stated minimum bend radius.		
Harness assembly	Bend radius is equal to or greater than the minimum bend radius of any individual wire/cable within the harness.		

Note 1: OD is the outer diameter of the wire or cable, including insulation.
Note 2: **Coaxial Fixed Cable –** Coaxial cable that is secured to prevent movement; not expected to have the cable repeatedly flexed during operation of the equipment.
Note 3: **Coaxial Flexible Cable –** Coaxial cable that is or may be flexed during operation of the equipment.

Acceptable - Class 1, 2, 3

- Minimum bend radius meets requirements of Table 4-1.

Defect - Class 1, 2, 3

- Bend radius is less than the minimum bend radius requirements of Table 4-1.

4.5.3 Routing – Coaxial Cable

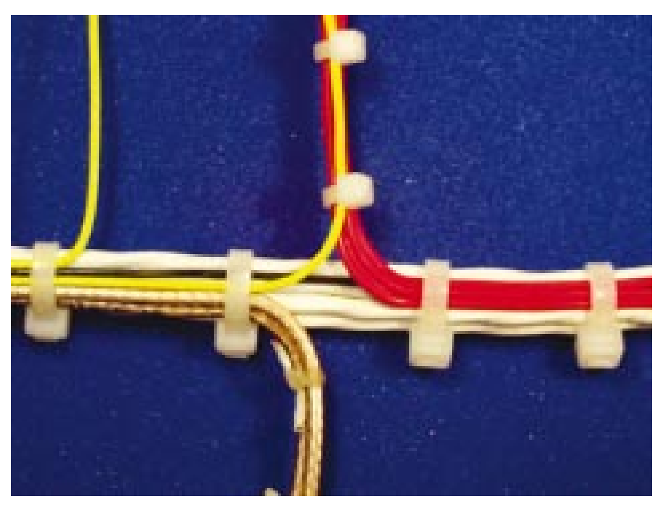


Figure 4-49

Acceptable - Class 1,2,3

- Inside bend radii meets the criteria of Table 4-1.

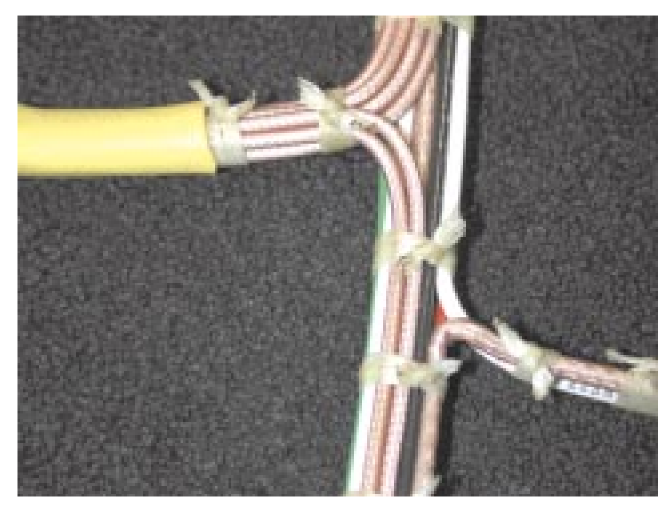


Figure 4-50

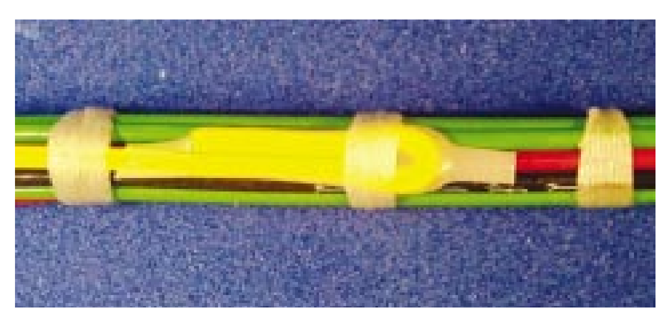
Defect - Class 1,2,3

- Inside bend radii does not meet the criteria of Table 4-1.

Defect - Class 3

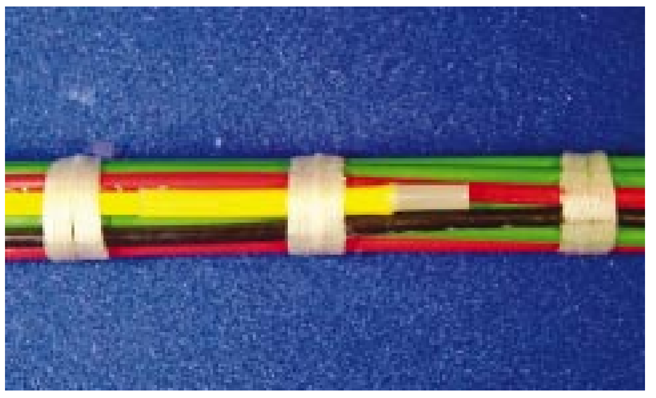
- Spot ties or tie wraps that cause any deformation of coaxial cables.

4.5.4 Routing – Unused Wire Termination


Figure 4-51

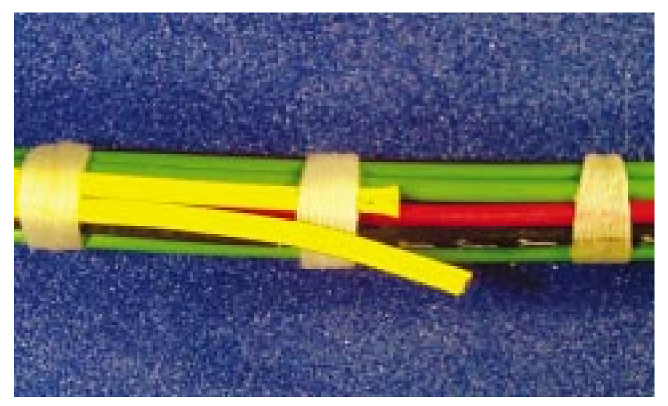
Target - Class 1,2,3

- Sleeving extends three wire diameters past end of wire.
- Unused wire is folded back and tied into the wire bundle.


Figure 4-52

Acceptable - Class 1,2,3

- Ends of unused wires are covered with shrink sleeving.
- Wire may extend straight down length of bundle (Figure 4-52) or be folded back (Figure 4-51).
- Sleeving extends at least 2 wire diameters beyond end of wire.
- Sleeving extends on to the wire insulation for a minimum of 4 wire diameters or 6 mm, whichever is greater.
- Unused wire is tied into the wire bundle.


Figure 4-53

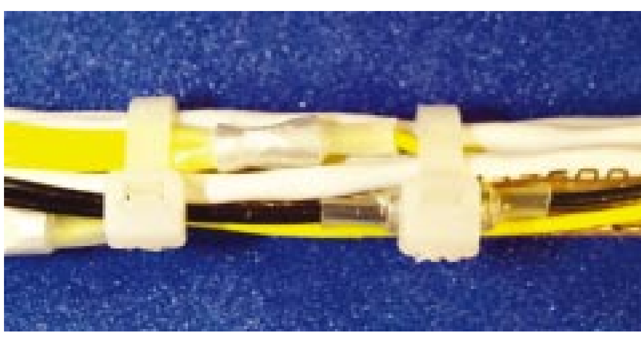
Defect - Class 1,2,3

- Ends of unused wires are exposed.
- Unused wire is not tied into the wire bundle.

Process Indicator - Class 2
Defect - Class 3

- Insulating sleeving extends beyond end of wire less than two wire diameters.
- Insulating sleeving extends onto wire insulation less than 4 wire diameters or 6 mm whichever is greater.

4.5.5 Routing – Ties over Splices and Ferrules


Figure 4-54

Acceptable - Class 1,2,3

- Spot ties or tie wraps/straps are placed near splices or solder ferrules contained in the wire bundle.
- No stress on wires exiting splices.

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Spot tie or tie wraps/straps are placed over splices or solder ferrules contained in the wire bundle.


Figure 4-55


Figure 4-56

Defect-Class 1,2,3

- Spot tie or tie wrap is placing stress on the wire(s) exiting the splice.

5 Soldering

This section establishes the acceptability requirements for soldered connections of all types, e.g., SMT, terminals, through-hole, etc. Although Class 1, 2 and 3 applications and environments have been considered, the nature of the soldering process may dictate that an acceptable connection will have the same characteristics for all three classes, and an unacceptable connection would be rejected for all three classes.

Where appropriate, the type of soldering process used has been addressed specifically in the criteria description. In any case, the connection criteria apply regardless of which methods of soldering have been utilized, for example:

- Soldering irons.
- Resistance soldering apparatus.
- Induction wave, or drag soldering.
- Reflow soldering.
- Intrusive soldering.

As an exception to the above, there are specialized soldering finishes, (e.g., immersion tin, palladium, gold, etc.) that require the creation of special acceptance criteria other than as stated in this document. The criteria should be based on design, process capability and performance requirements.

Wetting cannot always be judged by surface appearance. The wide range of solder alloys in use may exhibit from low or near zero degree contact angles to nearly 90° contact angles as typical. The acceptable solder connection must indicate evidence of wetting and adherence where the solder blends to the soldered surface.

The solder connection wetting angle (solder to component and solder to PCB termination) is not to exceed 90° (Figure 5-1 A, B). As an exception, the solder connection to a termination may exhibit a wetting angle exceeding 90° (Figure 5-1 C, D) when it is created by the solder contour extending over the edge of the solderable termination area or solder resist.

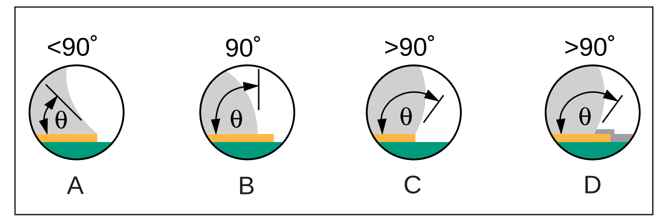


Figure 5-1

The primary difference between the solder connections created with processes using tin-lead alloys and processes using lead free alloys is related to the visual appearance of the solder. This standard provides visual criteria for inspection of both tin-lead and lead-free connections. Figures specific to lead-free connections will be identified with the symbol:

Acceptable lead-free and tin-lead connections may exhibit similar appearances but lead free alloys are more likely to have:

- Surface roughness (grainy or dull).
- Greater wetting contact angles.

All other solder fillet criteria are the same.

Typical tin-lead connections have from a shiny to a satin luster, generally smooth appearance and exhibit wetting as exemplified by a concave meniscus between the objects being soldered. High temperature solders may have a dull appearance. Touch-up (rework) of soldered connections is performed with discretion to avoid causing additional problems, and to produce results that exhibit the acceptability criteria of the applicable class.

5 Soldering (cont.)

The following topics are addressed in this section:

5.1 Soldering Acceptability Requirements

See 5.2 for examples of soldering anomalies.

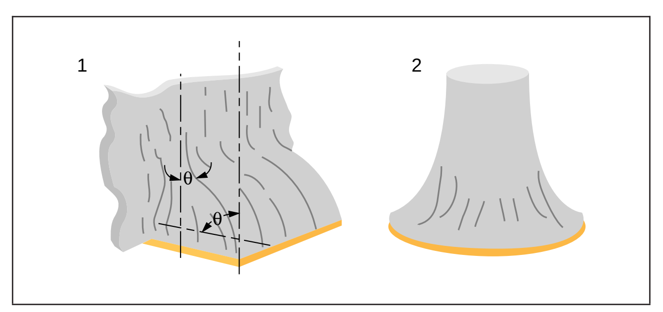


Figure 5-2

Target - Class 1,2,3

- Solder fillet appears generally smooth and exhibits good wetting of the solder to the parts being joined.
- Outline of the lead is easily determined.
- Solder at the part being joined creates a feathered edge.
- Fillet is concave in shape.

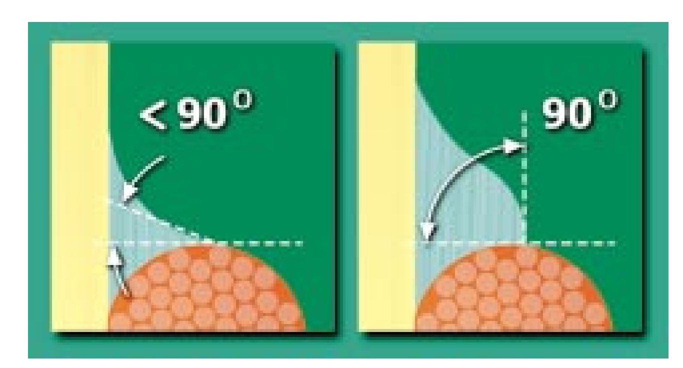


Figure 5-3

Acceptable - Class 1,2,3

- There are materials and processes, e.g., lead free alloys and slow cooling with large mass PCBs, that may produce dull matte, gray, or grainy appearing solders that are normal for the material or process involved. These solder connections are acceptable.
- The solder connection wetting angle (solder to component and solder to PCB termination) do not exceed 90° (Figure 5-1 A, B).
  - As an exception, the solder connection to a termination may exhibit a wetting angle exceeding 90° (Figure 5-1 C, D) when it is created by the solder contour extending over the edge of the solderable termination area or solder resist.

Figures 5-4 through 5-25 illustrate acceptable solder connections with various solder alloys and process conditions.

5.1 Soldering Acceptability Requirements (cont.)

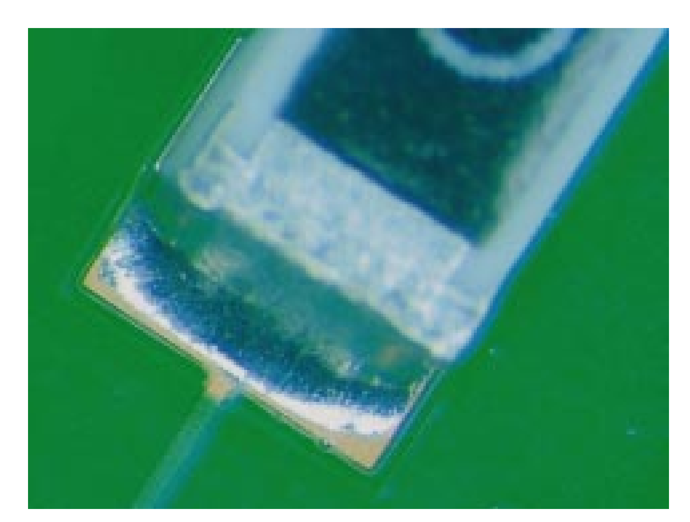


Figure 5-4 SnPb Solder; No Clean Process

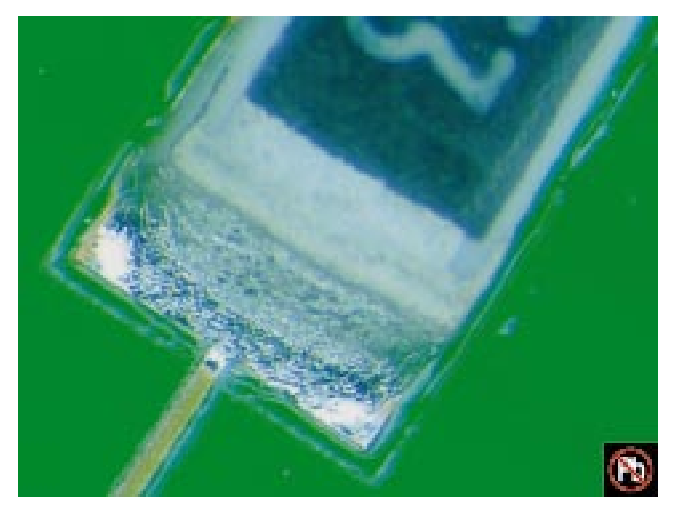


Figure 5-5 SnAgCu Solder; No Clean Process

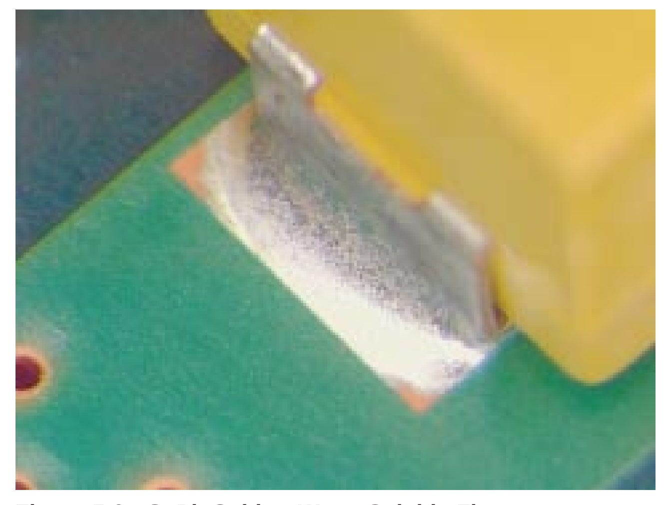


Figure 5-6 SnPb Solder; Water Soluble Flux

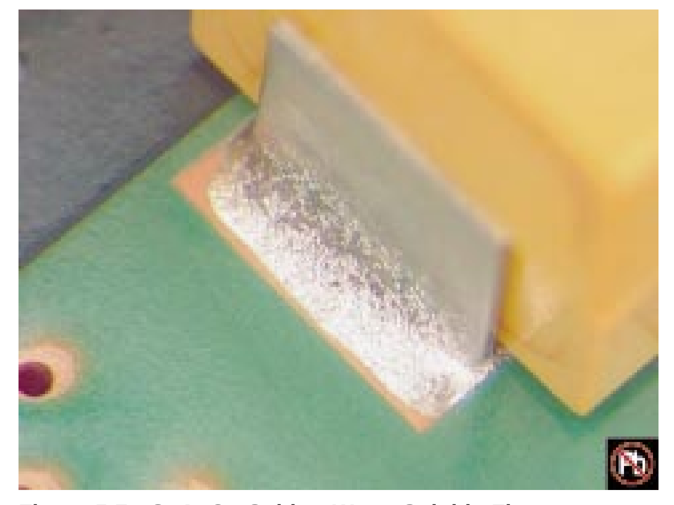


Figure 5-7 SnAgCu Solder; Water Soluble Flux

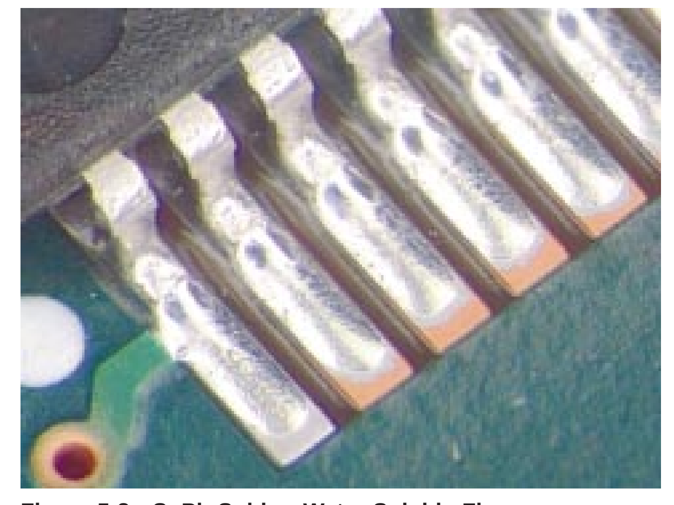


Figure 5-8 SnPb Solder; Water Soluble Flux

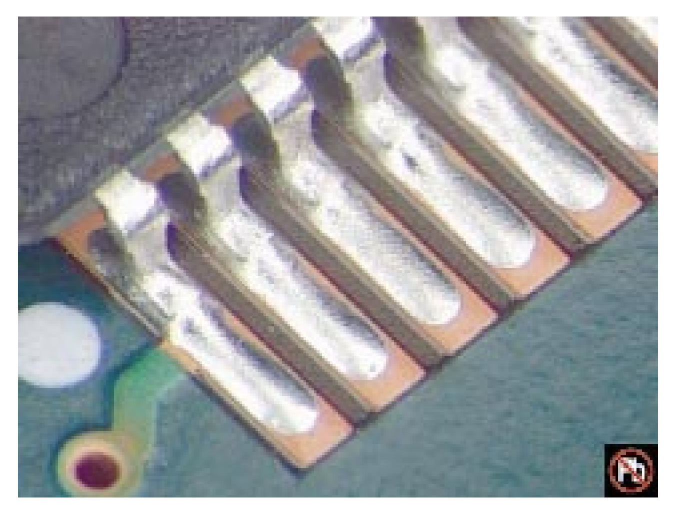


Figure 5-9 SnAgCu Solder; Water Soluble Flux

5.1 Soldering Acceptability Requirements (cont.)

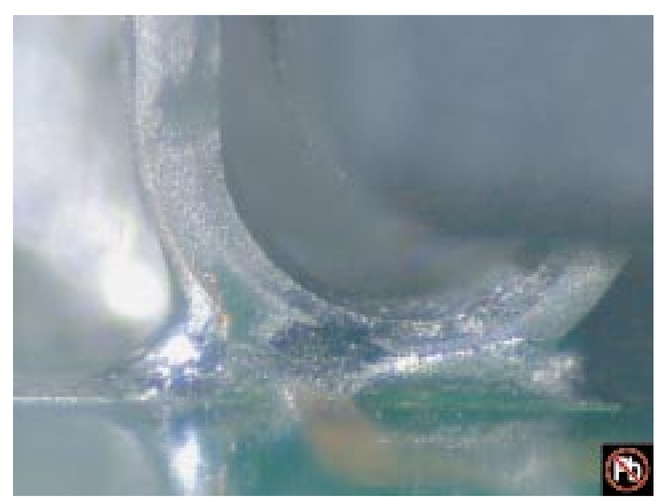


Figure 5-10 SnAgCu Solder; No Clean Process, N2 Reflow

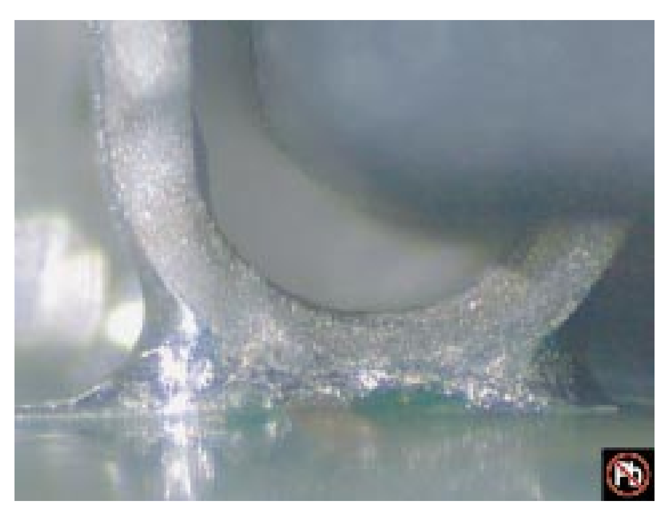


Figure 5-11 SnAgCu Solder, No Clean Process; Air Reflow



Figure 5-12 SnPb Solder; No Clean Process



Figure 5-13 SnAgCu Solder; No Clean Process

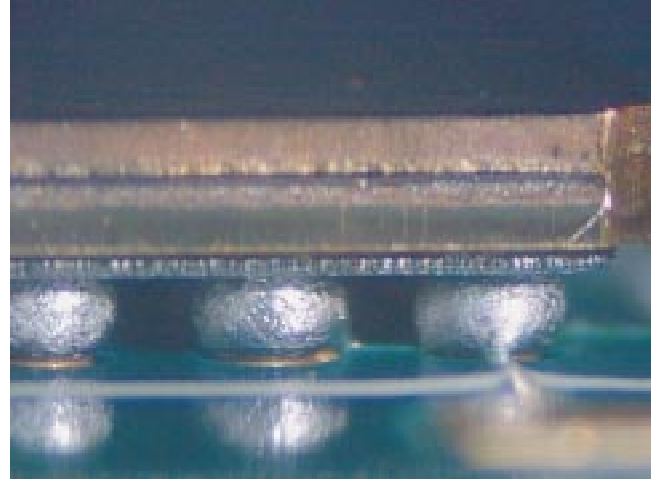


Figure 5-14 SnPb Solder; No Clean Process

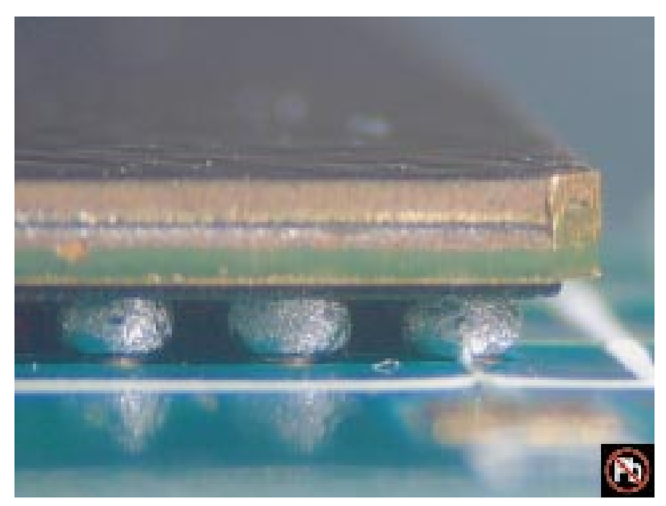


Figure 5-15 SnAgCu Solder; No Clean Process

5.1 Soldering Acceptability Requirements (cont.)

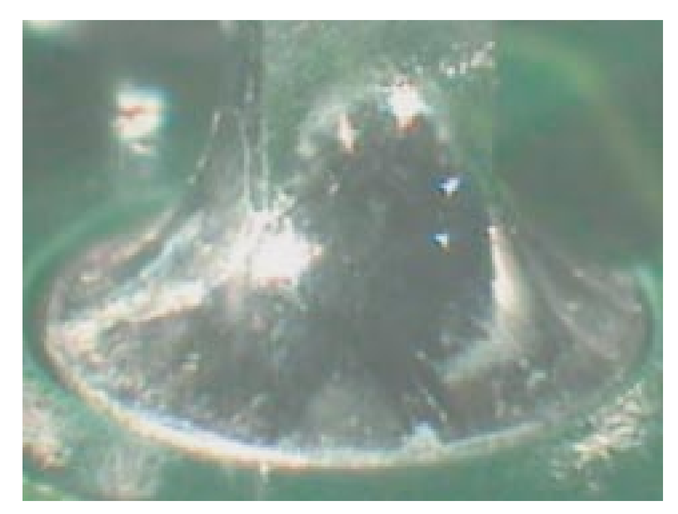


Figure 5-16 SnPb Solder



Figure 5-17 SnAgCu Solder

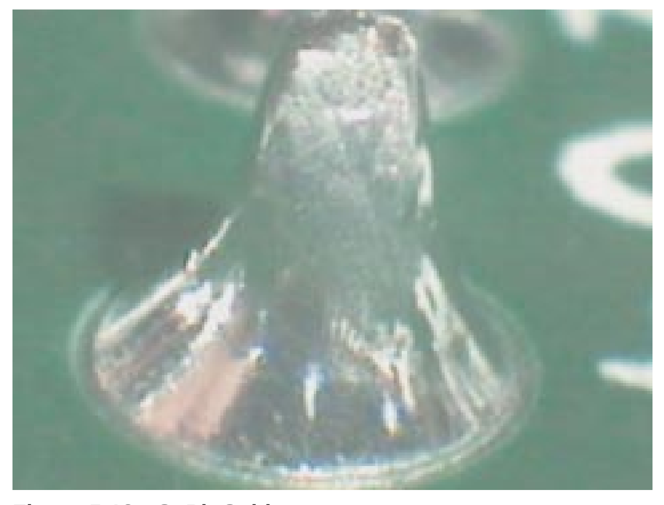


Figure 5-18 SnPb Solder

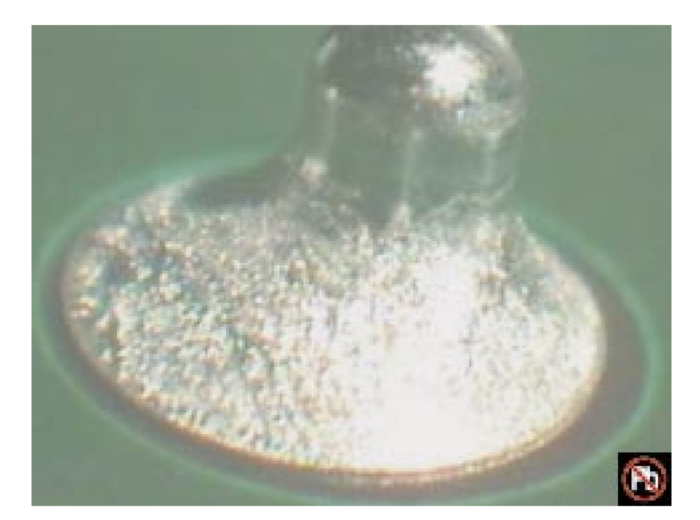


Figure 5-19 SnAgCu Solder

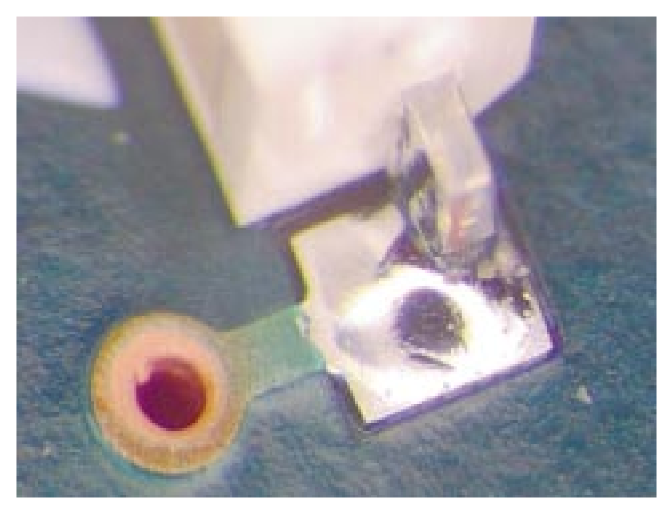


Figure 5-20 SnPb Solder; OSP Finish

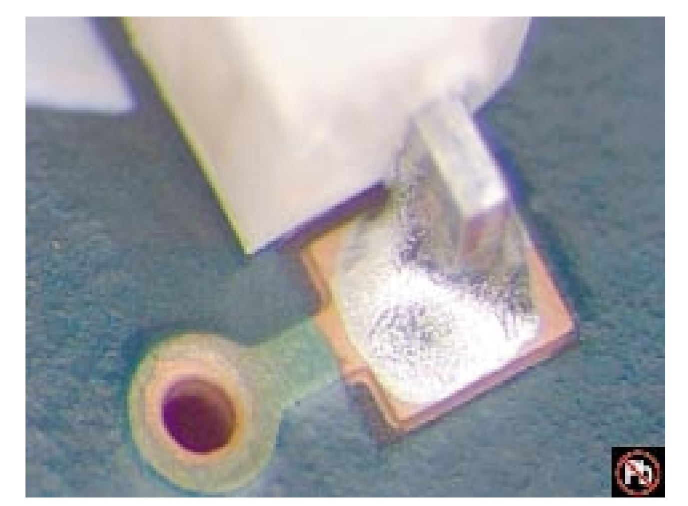


Figure 5-21 SnAgCu Solder; OSP Finish

5.1 Soldering Acceptability Requirements (cont.)



Figure 5-22 SnAgCu Solder



Figure 5-23 SnAgCu Solder



Figure 5-24 SnAgCu Solder

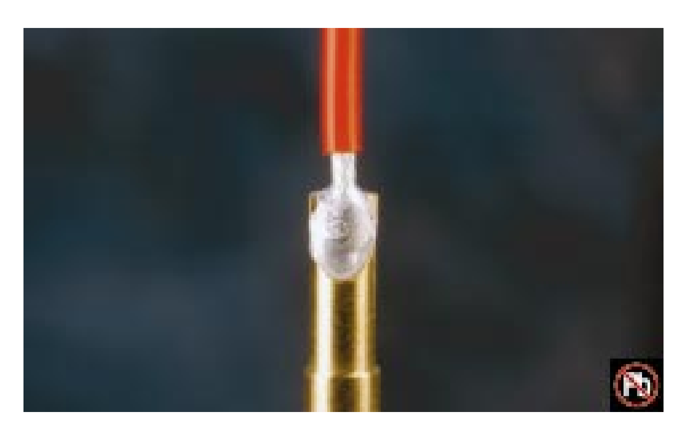


Figure 5-25 SnAgCu Solder

5.2 Soldering Anomalies

5.2.1 Soldering Anomalies – Exposed Basis Metal

Exposed basis metal on component leads, conductors or land surfaces from nicks, scratches, or other conditions cannot exceed the requirements of 7.1.2.3 for leads and 10.2.9.1 for conductors and lands.

Component leads, sides of land patterns, conductors, and use of liquid photoimageable solder resist, can have exposed basis metal per original designs.

Some printed circuit board and conductor finishes have different wetting characteristics and may exhibit solder wetting only to specific areas. Exposed basis metal or surface finishes should be considered normal under these circumstances, provided the achieved wetting characteristics of the solder connection areas are acceptable.

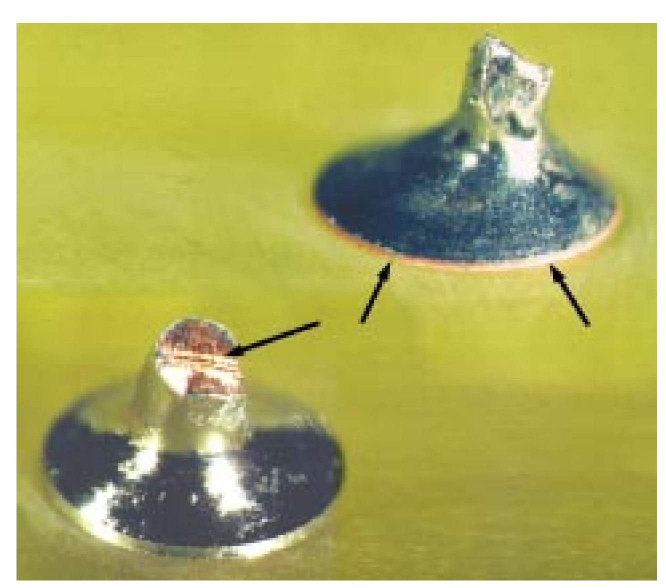


Figure 5-26

Acceptable - Class 1,2,3

- Exposed basis metal on:
  - Vertical conductor edges.
  - Cut ends of component leads or wires.
  - Organic Solderability Preservative (OSP) coated lands.
- Exposed surface finishes that are not part of the required solder fillet area.

5.2.1 Soldering Anomalies – Exposed Basis Metal (cont.)

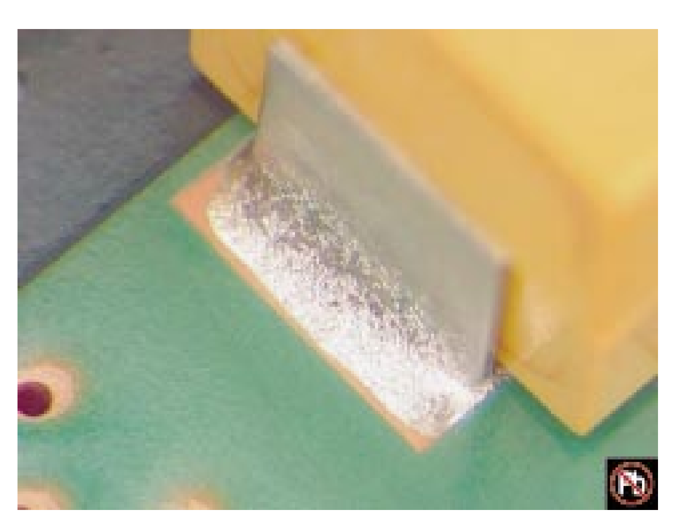


Figure 5-27

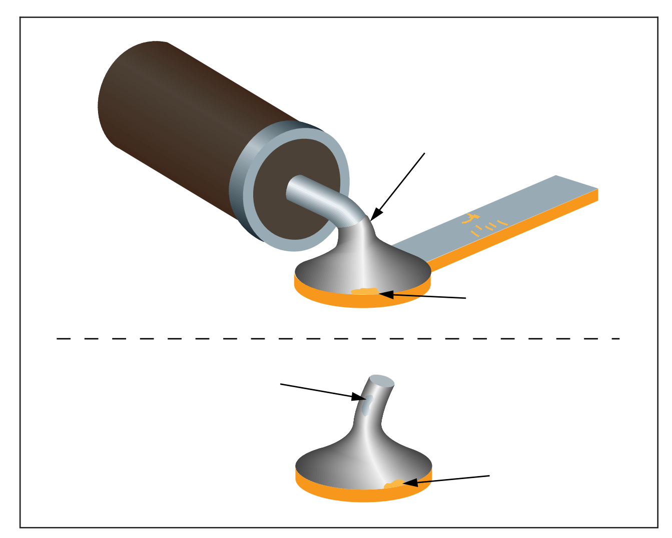


Figure 5-28

Acceptable - Class 1
Process Indicator - Class 2,3

- Exposed basis metal on component leads, conductors or land surfaces from nicks or scratches provided conditions do not exceed the requirements of 7.1.2.3 for leads and 10.2.9.1 for conductors and lands.

5.2.2 Soldering Anomalies – Pin Holes/Blow Holes

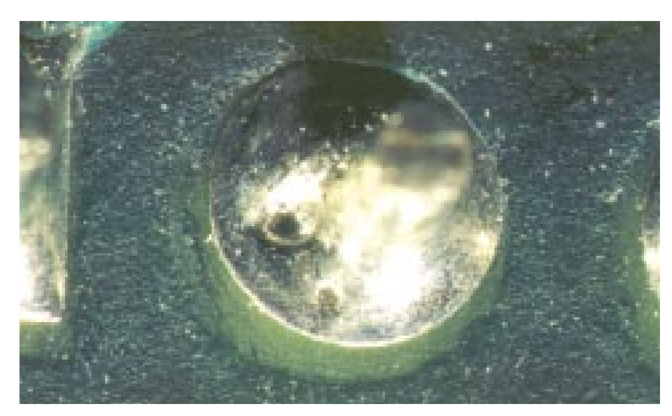


Figure 5-29



Figure 5-30

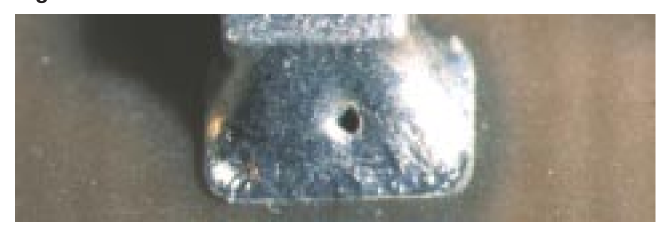


Figure 5-31



Figure 5-32

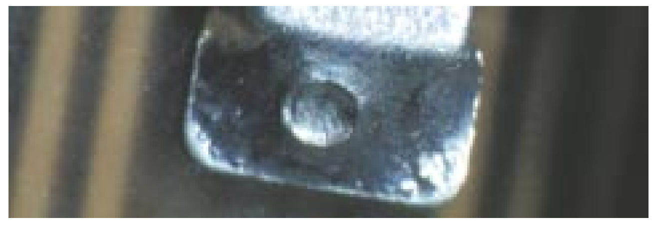


Figure 5-33

Acceptable - Class 1
Process Indicator - Class 2,3

- Blowholes (Figures 5-29, 30), pinholes (Figure 5-31), voids (Figures 5-32, 33), etc., providing the solder connection meets all other requirements.

Defect - Class 1,2,3

- Solder connections where pin holes, blow holes, voids, etc. reduce the connections below minimum requirements (not shown).

5.2.3 Soldering Anomalies – Reflow of Solder Paste



Figure 5-34

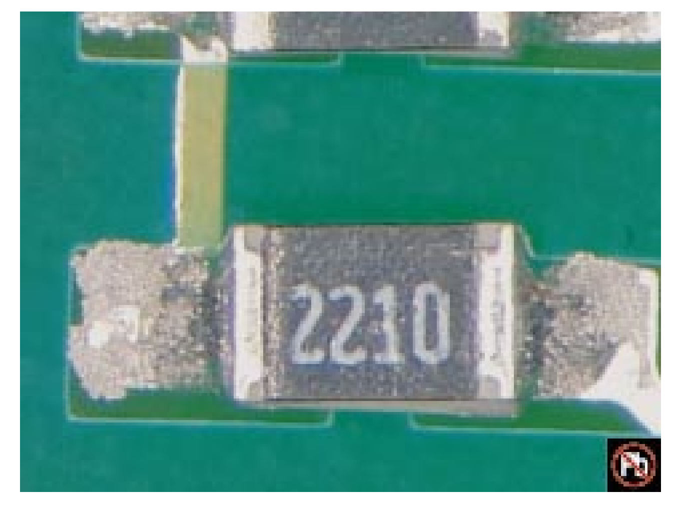


Figure 5-35

Defect - Class 1,2,3

- Incomplete reflow of solder paste.

5.2.4 Soldering Anomalies – Nonwetting

IPC-T-50 defines nonwetting as the inability of molten solder to form a metallic bond with the basis metal. In this Standard, that includes surface finishes, see 5.2.1.

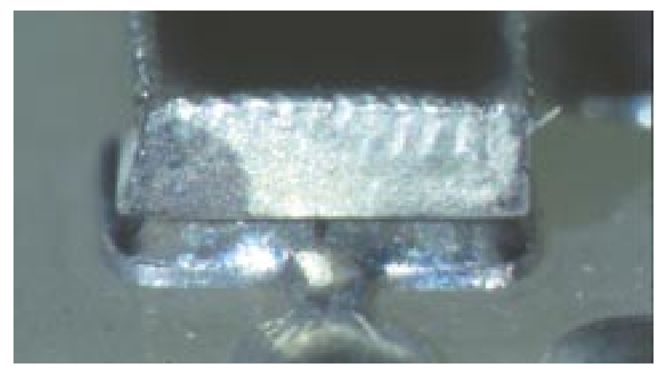


Figure 5-36

Defect - Class 1,2,3

- Solder has not wetted to the land or termination where solder is required.
- Solder coverage does not meet requirements for the termination type.



Figure 5-37



Figure 5-38



Figure 5-39

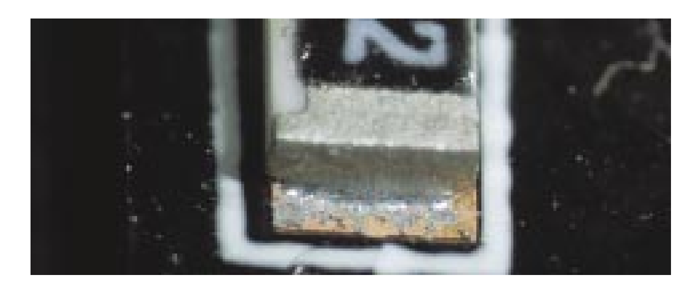


Figure 5-40

5.2.5 Soldering Anomalies – Dewetting

IPC-T-50 defines dewetting as a condition that results when molten solder coats a surface and then recedes to leave irregularly-shaped mounds of solder that are separated by areas that are covered with a thin film of solder and with the basis metal or surface finish not exposed.

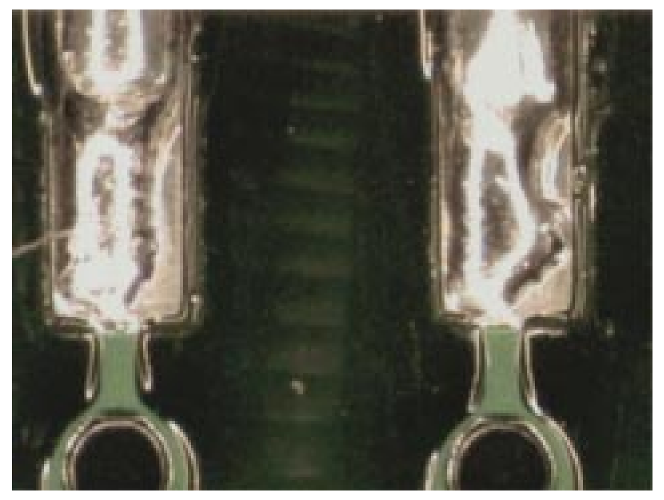


Figure 5-41

Defect - Class 1,2,3

- Evidence of dewetting that causes the solder connection to not meet the SMT or through-hole solder fillet requirements.

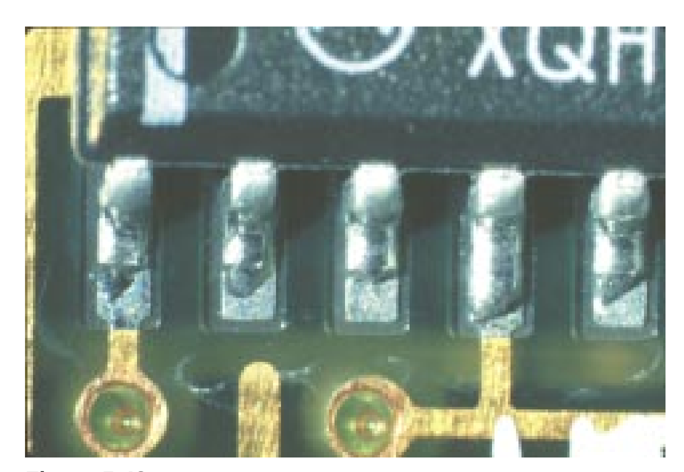


Figure 5-42

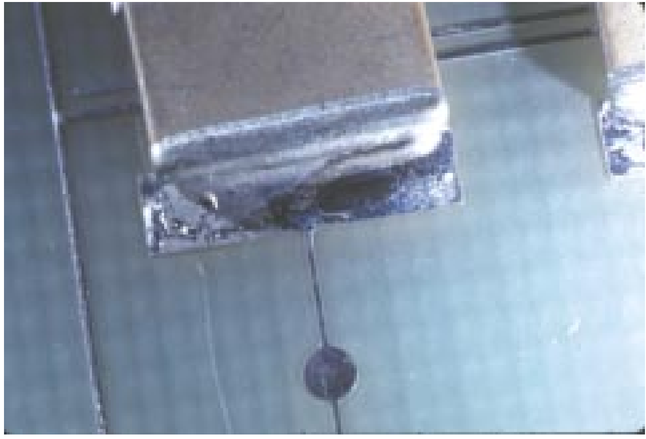


Figure 5-43

5.2.6 Soldering Anomalies – Excess Solder

5.2.6.1 Soldering Anomalies – Excess Solder – Solder Balls/Solder Fines

Solder balls are spheres of solder that remain after the soldering process. Solder fines are typically small balls of the original solder paste metal screen size that have splattered around the connection during the reflow process.

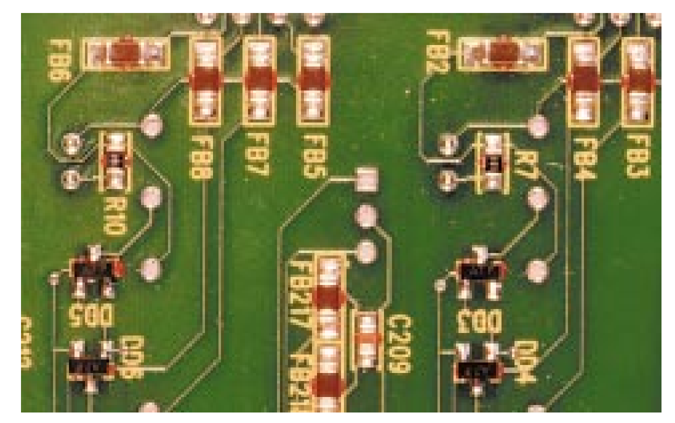


Figure 5-44

Target - Class 1,2,3

- No evidence of solder balls on the printed wiring assembly.

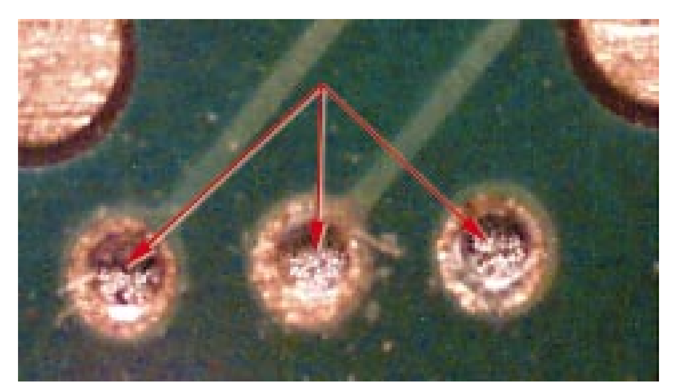


Figure 5-45

Acceptable - Class 1,2,3

- Solder balls are entrapped/encapsulated and do not violate minimum electrical clearance.

Note: Entrapped/encapsulated/attached is intended to mean that normal service environment of the product will not cause a solder ball to become dislodged.

5.2.6.1 Soldering Anomalies – Excess Solder – Solder Balls/Solder Fines (cont.)



Figure 5-46

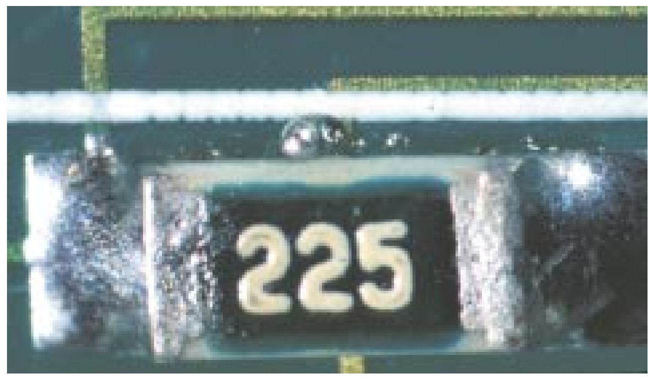


Figure 5-47

Defect - Class 1,2,3

- Solder balls violate minimum electrical clearance.
- Solder balls are not entrapped in no-clean residue or encapsulated with conformal coating, or not attached (soldered) to a metal surface, Figures 5-46 through 5-49.

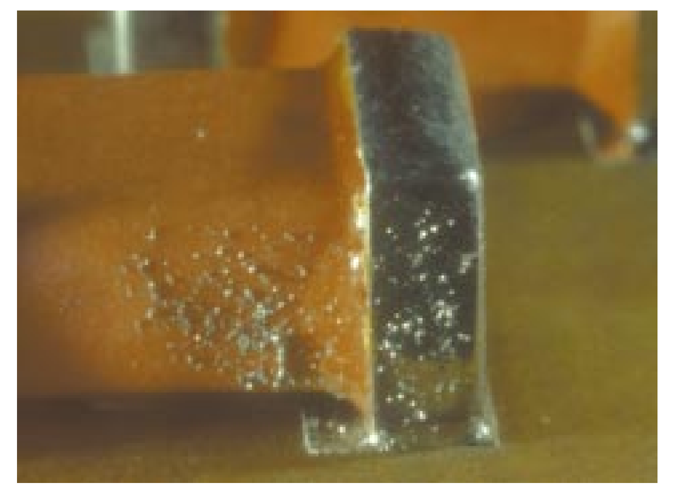


Figure 5-48

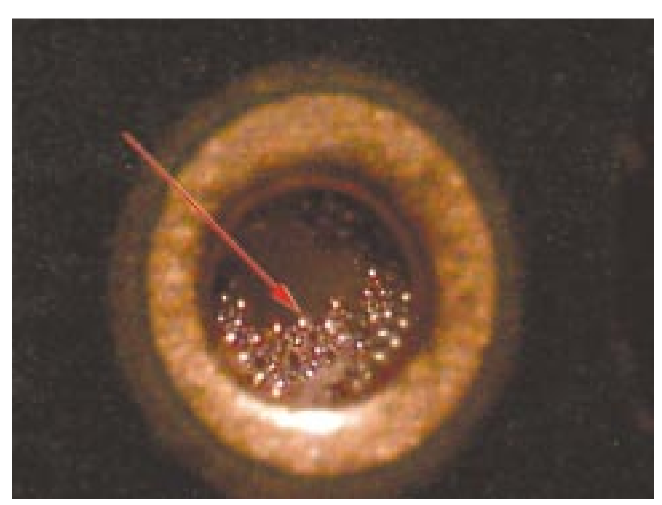


Figure 5-49

5.2.6.2 Soldering Anomalies – Excess Solder – Bridging

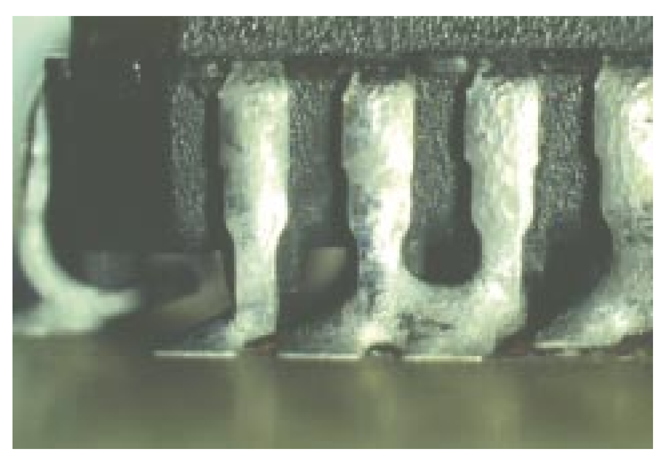


Figure 5-50

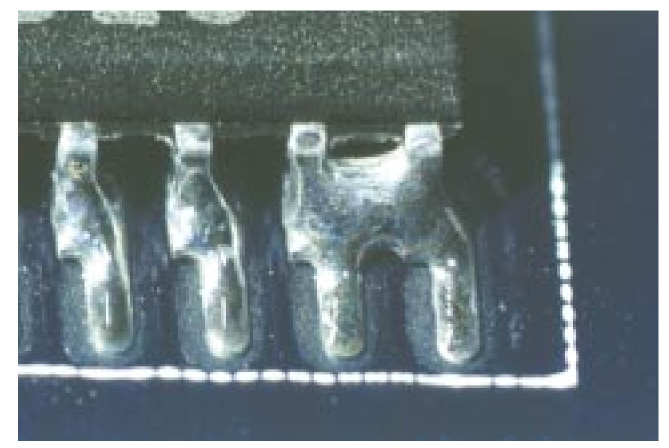


Figure 5-51

Defect - Class 1,2,3

- A solder connection across conductors that should not be joined.
- Solder has bridged to adjacent noncommon conductor or component.



Figure 5-52



Figure 5-53

5.2.6.3 Soldering Anomalies – Excess Solder – Solder Webbing/Splashes

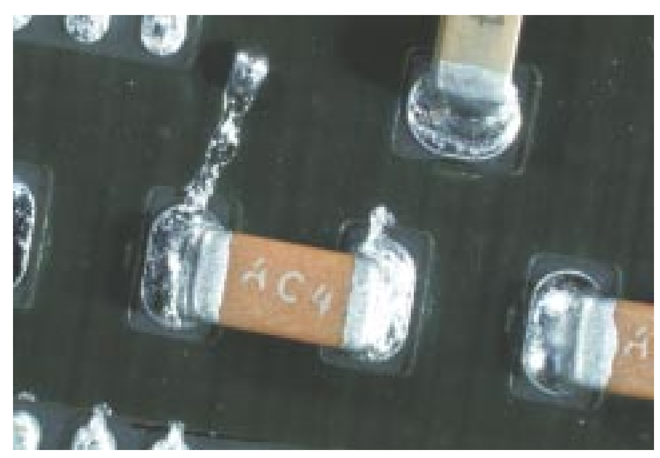


Figure 5-54

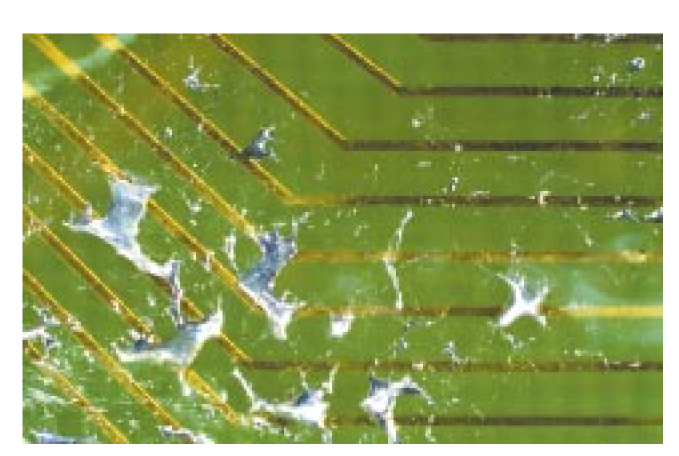


Figure 5-55

Defect - Class 1,2,3

- Solder splashes/webbing.

5.2.7 Soldering Anomalies – Disturbed Solder

Surface appearance with cooling lines as shown in Acceptable Figure 5-56 is more likely to occur in lead free alloys and is not a disturbed solder condition.

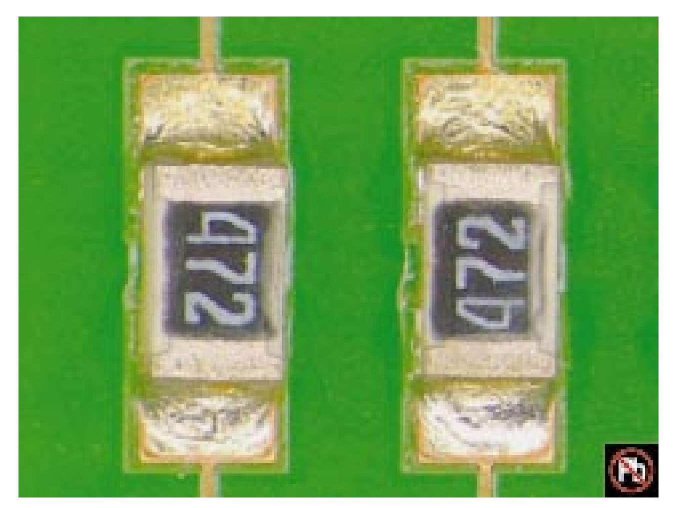


Figure 5-56



Figure 5-57

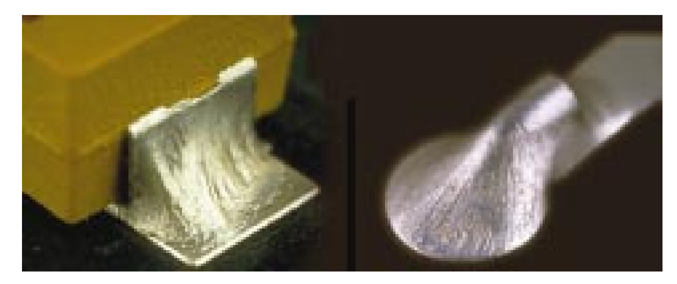


Figure 5-58



Figure 5-59

Defect - Class 1,2,3

- Disturbed solder joint characterized by stress lines from movement in the connection.

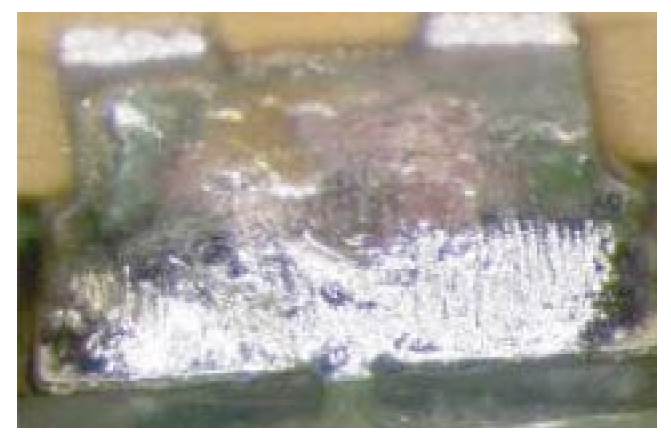


Figure 5-60

5.2.8 Soldering Anomalies – Fractured Solder

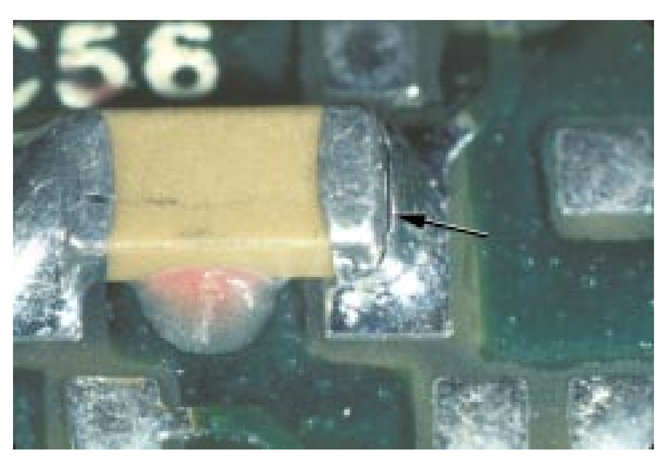


Figure 5-61

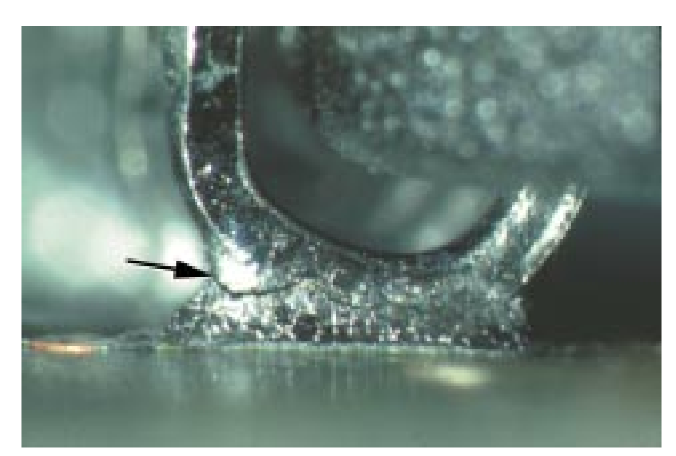


Figure 5-62

Defect - Class 1,2,3

- Fractured or cracked solder.

5.2.9 Soldering Anomalies – Solder Projections

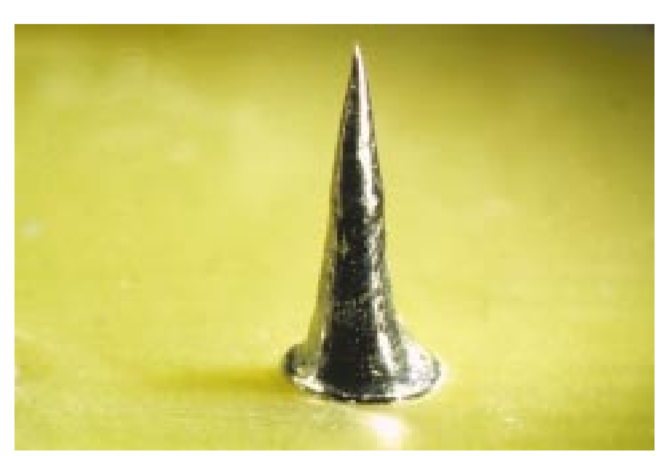


Figure 5-63

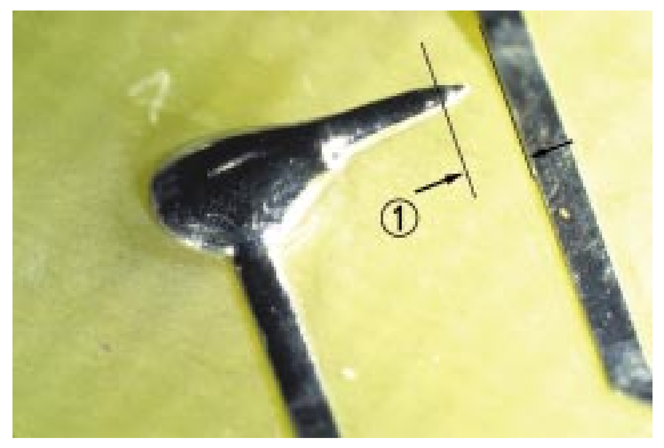


Figure 5-64

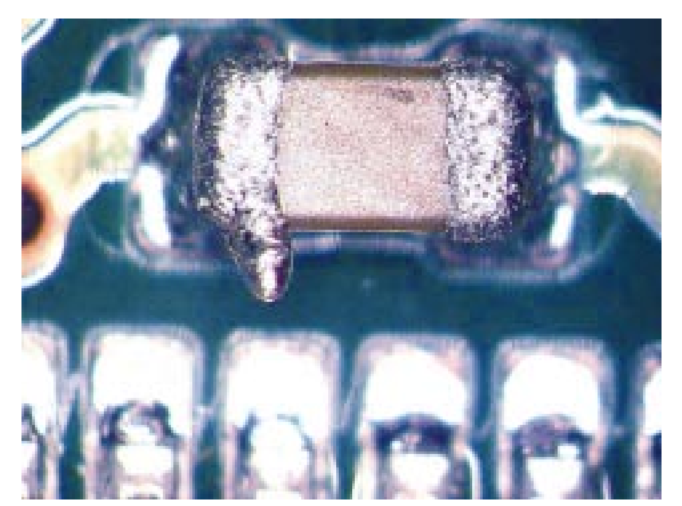


Figure 5-65

Defect - Class 1,2,3

- Solder projection, Figure 5-63, violates assembly maximum height requirements or lead protrusion requirements.
- Projection, Figure 5-64 violates minimum electrical clearance (1).

5.2.10 Soldering Anomalies – Lead Free – Fillet Lift

These criteria are applicable to plated-through hole connections.



Figure 5-66

Acceptable - Class 1,2.3

- Fillet lifting - separation of the bottom of the solder and the top of the land on the primary side of plated-through hole connection.

Process Indicator - Class 2
Defect - Class 3

- Fillet lifting - separation of the bottom of the solder and the top of the land on the secondary side of plated-through hole connection (not shown).

Defect - Class 1,2,3

- Fillet lifting damages the land attachment, see 10.2.9.2.

5.2.11 Soldering Anomalies – Hot Tear/Shrink Hole



Figure 5-67

Acceptable - Class 1,2,3

- For connections made with lead free alloys:
  - The bottom of the tear is visible.
  - The tear or shrink hole does not contact the lead, land or barrel wall.

Defect - Class 1,2,3

- Shrink holes or hot tear in connections made with SnPb solder alloys:
- For connections made with lead free alloys:
  - The bottom of the shrink hole or hot tear is not visible.
  - The tear or shrink hole contacts the lead or land.

6 Terminal Connections

These criteria apply to both wires and component leads. The preferred wrap conditions achieve a mechanical connection between the lead/wire and the terminal sufficient to assure that the lead/wire does not move during the soldering operation. Typically the mechanical connection includes a 180° mechanical wrap to effect mechanical connection.

As an exception to the wrap conditions described above, it is acceptable when attaching leads/wires to bifurcated, slotted, pierced, punched or perforated terminals for the lead/wire to extend straight through the opening of the terminal with no wrap. Except for slotted terminals (6.7.4), leads/wires with no wrap need to be staked, bonded, or constrained to a degree that the attachment is mechanically supported to prevent transmission of shock, vibration, and movement of the attached wires that could degrade the solder connection.

The criteria in this section are grouped together in eleven main subsections. Not all combinations of wire/lead types and terminal types can possibly be covered explicitly, so criteria is typically stated in general terms to apply to all similar combinations. For example, a resistor lead and a multistranded jumper wire connected to turret terminals have the same wrap and placement requirements, but only the multistranded wire could be subject to birdcaging.

In addition to the criteria in this section, solder connections must meet the criteria of Section 5.

The following topics are addressed in this section:

6.1 Edge Clip

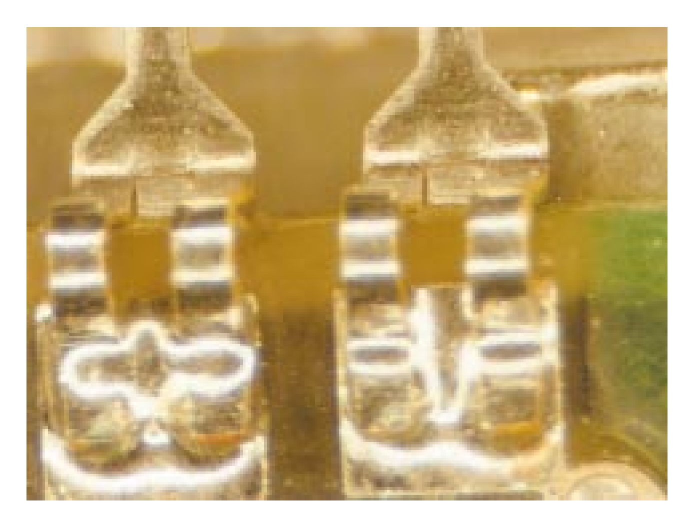


Figure 6-1

Target - Class 1,2,3

• Clip is centered on land with no side overhang.



Figure 6-2

Acceptable - Class 1,2,3

• Clip has 25% maximum overhang off land.

• Overhang does not reduce spacing below minimum electrical clearance.

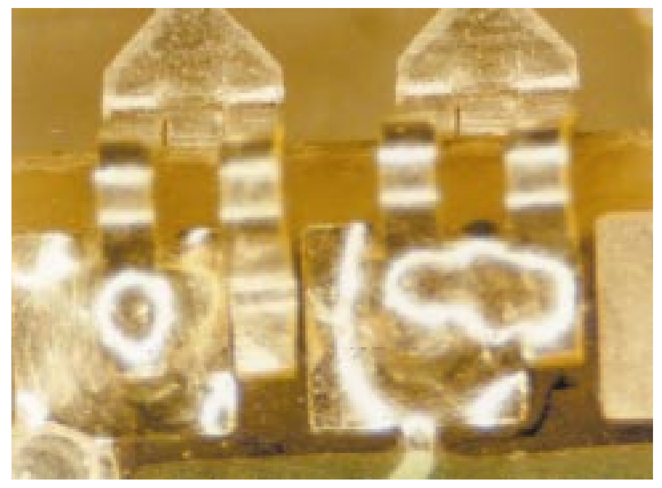


Figure 6-3

Defect - Class 1,2,3

• Clip exceeds 25% overhang off land.

• Clip overhangs land, reducing the spacing below minimum electrical clearance.

6.2 Swaged Hardware

This section contains criteria for the basic types of swaged hardware.

Terminals

Swaged hardware that overhangs the land is acceptable if it does not violate minimum electrical clearance, see 1.4.5.

Solderability

Plating and solderability of swaged hardware should be consistent with appropriate plating and solderability specifications. See IPC/EIA J-STD-002 and IPC/EIA J-STD-003 for solderability requirements.

6.2.1 Swaged Hardware – Rolled Flange

The rolled flange terminal is used for mechanical attachments where electrical attachment to a land is not required. Rolled flange attachments are not soldered to a PCB land pattern or installed on active circuitry. They may be installed on inactive and isolated circuitry.

Target - Class 1,2,3

- Rolled flange is uniformly swaged and concentric to the attachment hole.
- Flange compression is sufficient to support the mechanical attachment of the terminal for the intended performance environment.
- Terminal does not rotate or move once swaged.
- No splits or cracks in the terminal swage.
- Terminal post or attachment is perpendicular to the assembly surface.
- The lip of the rolled flange is in full contact with the base laminate for the full circumference of the flange.
- No laminate damage.

Acceptable - Class 1,2,3

- Burnishing and deformation required to form the terminal swage.
- Up to three radial splits or cracks separated by at least 90°.
- Minor damage of the substrate.
- No circumferential splits or cracks.
- Splits or cracks do not enter the terminal shank.

Defect - Class 1,2,3

- Any circumferential splits or cracks.
- Any splits or cracks that enter the terminal shank.
- More than three radial splits or cracks.
- Splits or cracks that are not separated by more than 90°.
- Missing rolled flange pieces.
- Terminals installed on active circuitry or PTHs.
- Soldered rolled flange terminals.
- Any mechanical damage of the substrate beyond requirements; see 10.2.

6.2.2 Swaged Hardware – Flared Flange

The shank extending beyond the land surface is swaged to create an inverted cone, uniform in spread, and concentric to the hole.

The flange is not split, cracked or otherwise damaged to the extent that flux, oils, inks, or other liquid substances utilized for processing the printed wiring assemblies can be entrapped within the mounting hole.



Figure 6-4

Target - Class 1,2,3

- Flared flange is uniformly swaged and concentric to the hole.
- Strain or stress marks caused by flaring are kept to a minimum.
- The flange is swaged sufficiently tight to prevent movement in the Z-axis.



Figure 6-5

Acceptable - Class 1,2,3

- Split in flared flange does not enter into the barrel.
- Not more than three radial splits.
- Any radial splits are separated by at least 90°.

Figure 6-6

Acceptable - Class 1

- Split in flared flange in barrel acceptable if soldered after swaging.

Defect - Class 1,2,3

- Flared flange periphery uneven or jagged.
- Split enters into barrel; see Class 1 exception above.
- Any circumferential splits/cracks.
- More than three radial splits.
- Any two radial splits separated by less than 90°.

6.2.3 Swaged Hardware – Controlled Split

This form of swaged hardware is obtained by using scored hardware with a number of uniform segments. When swaged, each segment should conform to a particular angle.

Controlled split hardware is to be soldered as soon as possible after swaging to avoid oxidation.



Figure 6-7

Target - Class 1,2,3

- Flange is uniformly split and concentric to the hole.
- Split segments do not extend to the outside diameter of the land.
- Flange is swaged sufficiently tight to prevent movement in the Z-axis.



Figure 6-8

Acceptable - Class 1,2,3

- Flange splits down to the board but not into the barrel.
- No circumferential splits or cracks.

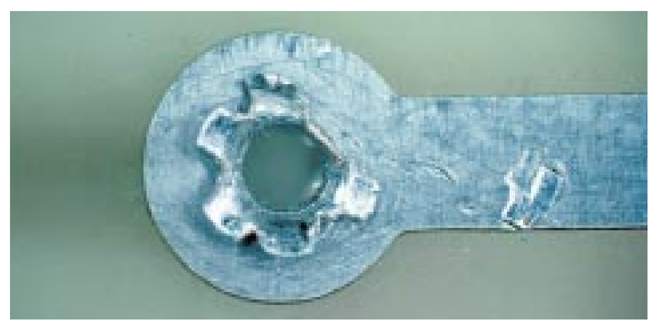


Figure 6-9



Figure 6-10

Acceptable - Class 1
Defect - Class 2,3

- Flange damaged.
- Segments excessively deformed.
- Segment missing.
- Split enters into barrel.
- Any circumferential splits/cracks.

6.2.4 Swaged Hardware – Terminals

This section shows mechanical assembly of turret and bifurcated terminals. Terminals that are to be soldered to a land may be mounted so that they can be turned by hand, but are vertically stable.

6.2.4.1 Swaged Hardware – Terminals – Turret

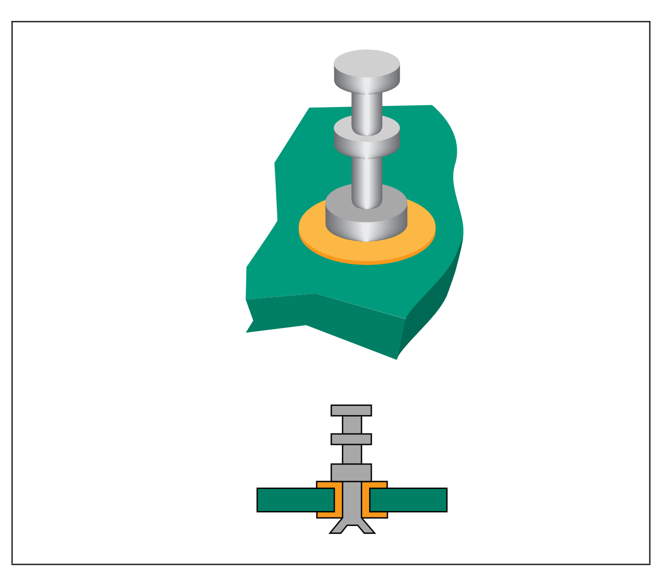


Figure 6-11

Target - Class 1,2,3

- Terminal intact and straight.

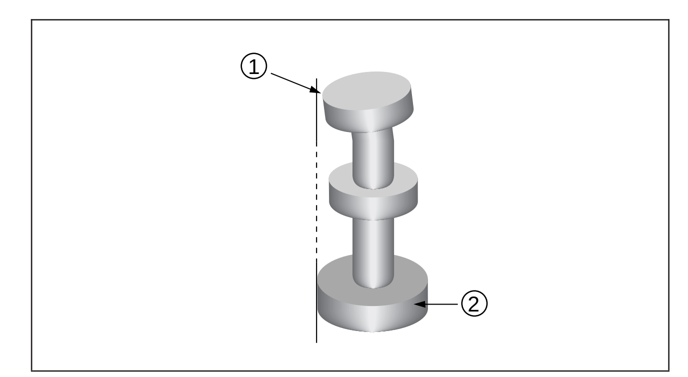


Figure 6-12
1. Top edge
2. Base

Acceptable - Class 1,2,3

- Terminal is bent, but the top edge does not extend beyond the base.

Acceptable - Class 1
Defect - Class 2,3

- The top edge of the terminal is bent beyond the edge of the base.

Defect - Class 1,2,3

- The center post is fractured.

6.2.4.2 Swaged Hardware – Terminals – Bifurcated

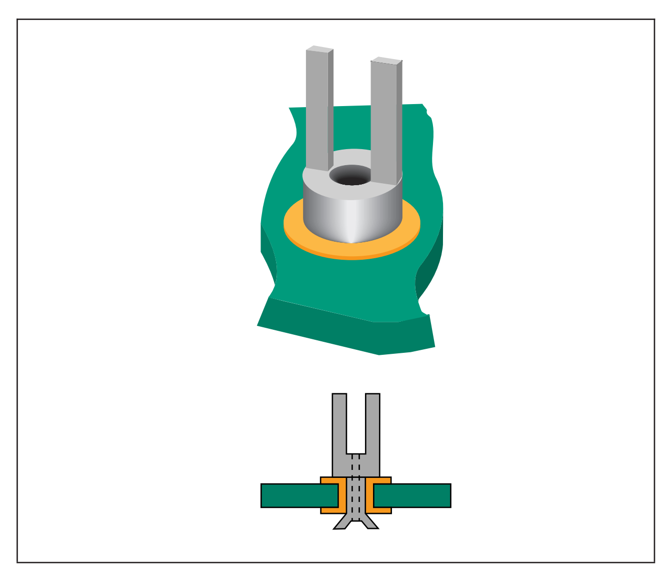


Figure 6-13

Target - Class 1,2,3

- Terminal intact and straight.

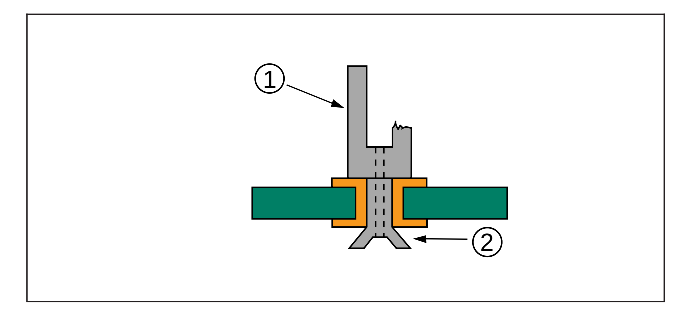


Figure 6-14
1. Top edge
2. Base

Acceptable - Class 1
Defect - Class 2,3

- A post is broken, but sufficient mounting area remains to attach the specified wires/leads.

Defect - Class 1,2,3

- Both posts are broken.

6.2.5 Swaged Hardware – Fused in Place

The flange is not split, cracked or otherwise damaged to the extent that flux, oils, inks, or other liquid substances utilized for processing the printed board can be entrapped within the mounting hole. After swaging, the area is to be free of circumferential splits or cracks.

The manufactured flange (head) of the eyelet needs to be in full contact with the land area.



Figure 6-15

Target - Class 1,2,3

- Solder around periphery of flange.
- Good filleting of solder around flange.
- Good wetting of flange and terminal area.
- The swaged flange needs to be as close to the land as possible to prevent movement in the Z axis.
- Evidence of solder flow is discernible between swaged flange and land of the printed board or other substrate.

6.2.5 Swaged Hardware – Fused in Place (cont.)



Figure 6-16

Acceptable - Class 1,2

- Solder is around minimum of 270° of flange.
- Any radial split is filled with solder.
- Fillet of solder to at least 75% of flange height.

Acceptable - Class 3

- Solder is around minimum of 330° of flange.
- No radial or circumferential splits.
- Fillet of solder to at least 75% of flange height.



Figure 6-17

Defect - Class 1,2

- Solder is less than 270° around flared flange or eyelet periphery.

Defect - Class 1,2,3

- Improperly swaged, flange not seated on terminal area.
- Any radial split not filled with solder.
- Solder does not reach up to 75% of flared flange height or 100% of flat set eyelet height.
- Circumferential split of flared flange or eyelet.

Defect - Class 3

- Solder is around less than 330° of flange.
- Any radial or circumferential split in flange.

6.3 Wire/Lead Preparation – Tinning

In this document, the term pretinning and tinning have the same meaning, as defined in IPC-T-50: The application of molten solder to a basis metal in order to increase its solderability.

Tinning of stranded wire has the added benefit of bonding the individual wire strands together, thereby allowing the wire to be formed to terminals or attachment points without separation of the individual strands (birdcaging).

The following criteria are applicable if tinning is required.



Figure 6-18

Target - Class 1,2,3

- Stranded wire is uniformly coated with a thin coat of solder with the individual strands of the wire easily visible.
- Untinned length of strands from end of insulation is not greater than one wire diameter (D).

Acceptable - Class 1,2,3

- The solder wets the tinned portion of the wire and penetrates to the inner strands of stranded wire.
- Solder wicks up wire provided the solder does not extend to a portion of the wire that is required to remain flexible.
- The tinning leaves a smooth coating of solder and the outline of the strands are discernible.

Process Indicator - Class 2,3

- Strands are not discernible but excess solder does not affect form, fit or function.
- Solder does not penetrate to the inner strands of the wire.

6.3 Wire/Lead Preparation – Tinning (cont.)



Figure 6-19

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Pinholes, voids or dewetting/nonwetting exceeds 5% of the area required to be tinned.
- Length of untinned strands from end of insulation is greater than one wire diameter.

Note: IPC/EIA J-STD-002 provides additional information for assessing this requirement.

Defect - Class 2,3

- Solder does not wet the tinned portion of the wire.
- Stranded wire is not tinned prior to attachment to terminals or forming splices (other than mesh).

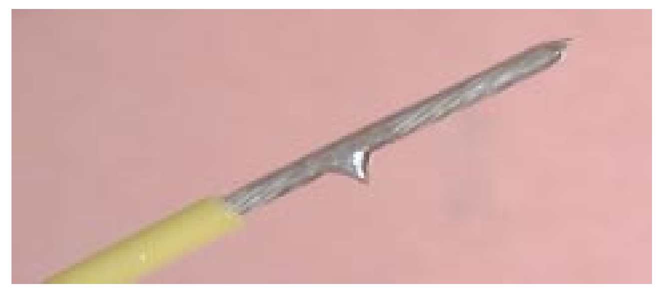


Figure 6-20

Defect - Class 1,2,3

- Solder wicking extends into the portion of wire that is required to remain flexible after soldering.
- Solder build-up or icicles within the tinned wire area that affect subsequent assembly steps.

6.4 Lead Forming – Stress Relief

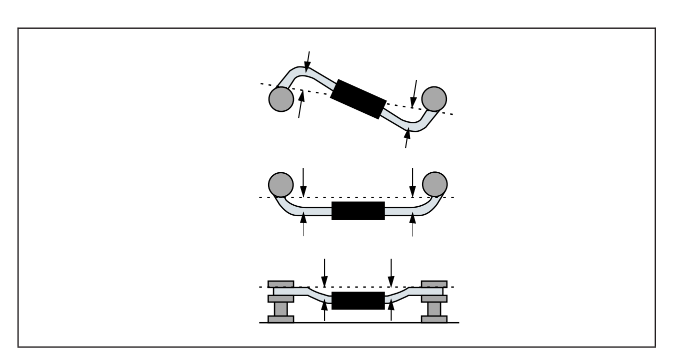


Figure 6-21

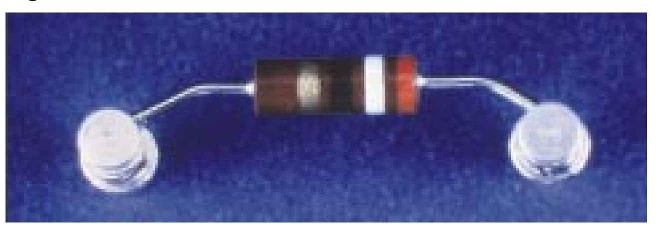


Figure 6-22

Target - Class 1,2,3

- Component body centerline to terminal edge is at least one-half (50%) the component diameter or 1.3 mm [0.0511 in], whichever is greater.
- Clip and adhesive mounted component leads have stress relief.

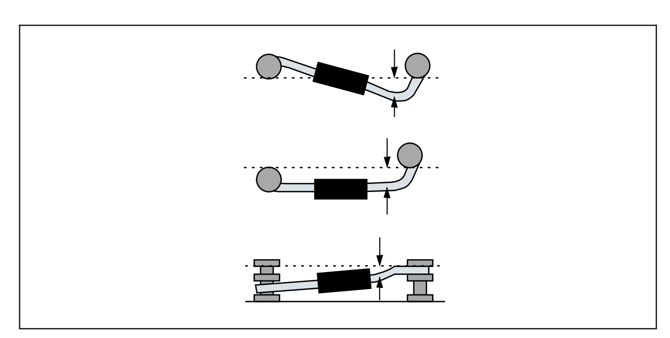


Figure 6-23

Acceptable - Class 1,2,3

- One lead has minimal stress relief bend, provided the component is not clip or adhesive mounted, or otherwise constrained.
- All leads have minimal stress relief bend when the component is clipped or adhesive mounted or otherwise constrained.

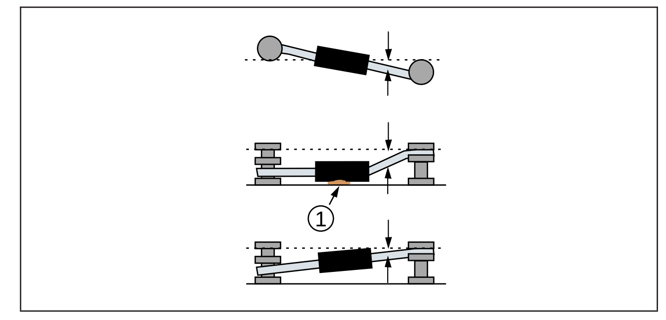


Figure 6-24
1. Adhesive

Defect - Class 1,2,3

- No stress relief.
- Stress relief not present in all leads of a constrained component.

6.5 Service Loops

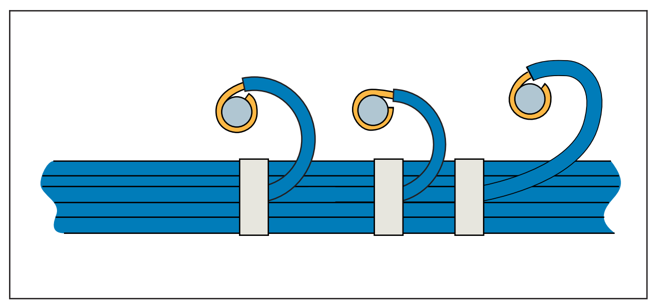


Figure 6-25

Acceptable - Class 1,2,3

- Sufficient service loop is provided to allow one field repair to be made.

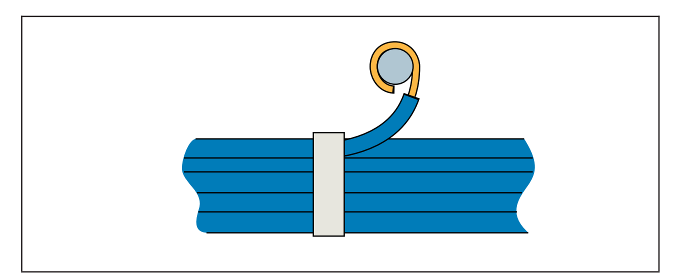


Figure 6-26

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- The wire is too short to allow an additional wrap if repair is necessary.

6.6 Terminals – Stress Relief Lead/Wire Bend

6.6.1 Terminals – Stress Relief Lead/Wire Bend – Bundle

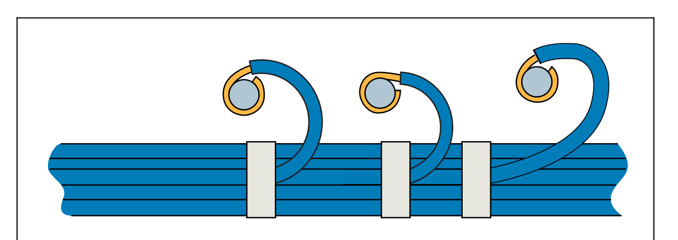


Figure 6-27

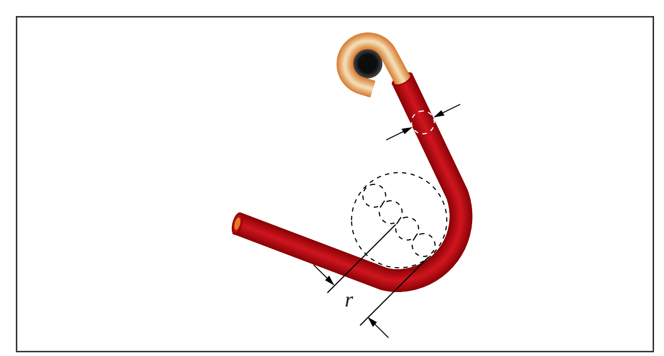


Figure 6-28

Acceptable - Class 1,2,3

- The wire approaches the terminal with a loop or bend sufficient to relieve any tension on the connection during thermal/vibration stress (Figure 6-27).
- The direction of the stress-relief bend places no strain on the mechanical wrap or the solder connection.
- Bend not touching terminal is in conformance with Table 7-1 (Figure 6-28).

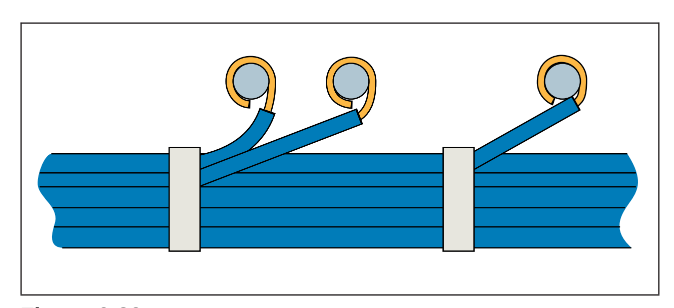


Figure 6-29

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- There is insufficient stress relief.
- The wire is under stress at the wrap.

6.6.2 Terminals – Stress Relief Lead/Wire Bend – Single Wire

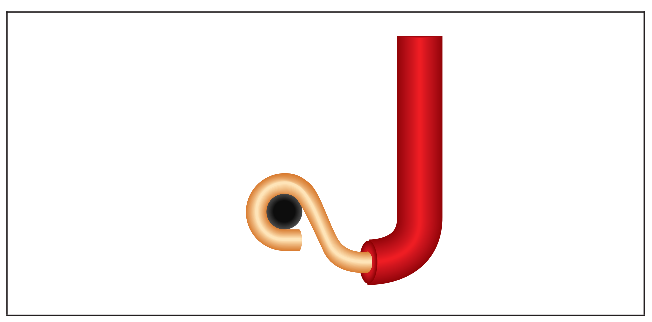


Figure 6-30

Acceptable - Class 1
Defect - Class 2,3

- The wire is formed around the terminal opposite to the feed-in direction.

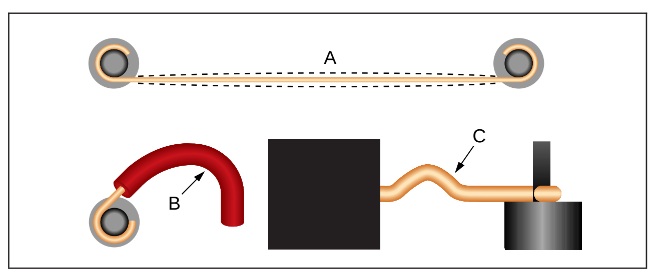


Figure 6-31

Acceptable - Class 1,2,3

- The wire is straight between the connections with no loop or bend, but wire is not taut (A).
- Bends are not kinked (B, C). See Table 7-1.

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Does not meet bend radius requirements. See Table 7-1.

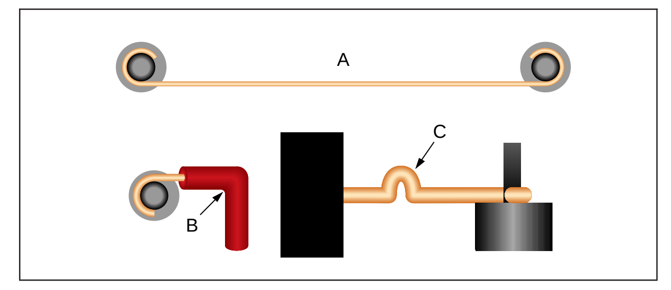


Figure 6-32

Defect - Class 1,2,3

- Wire is stretched taut between the terminals. (A)
- Bend radius does not meet the requirements of Table 7-1 (B).
- Bends are kinked. (C)

6.7 Lead/Wire Placement

Applies equally to wires and component leads. The criteria associated with each terminal type or connection in clauses 6.7.1 through 6.7.9 apply only to that connection.

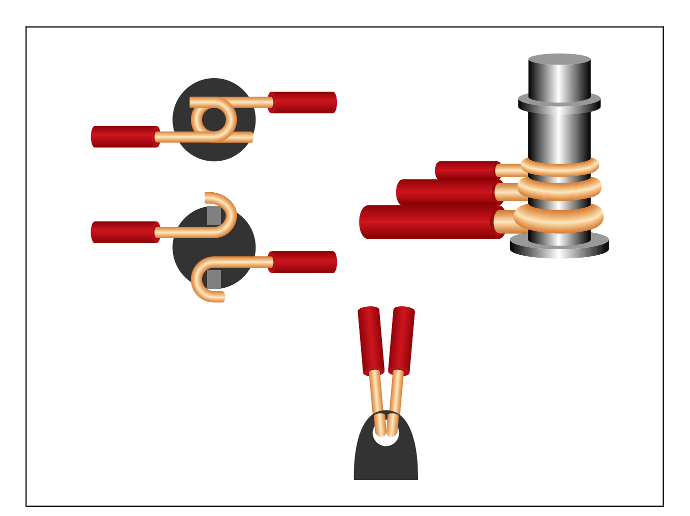


Figure 6-33

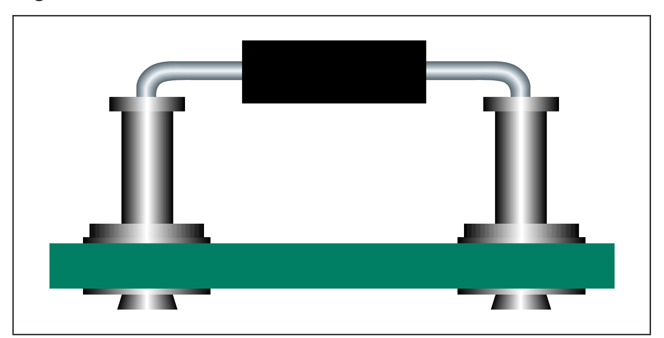


Figure 6-34

Acceptable - Class 1,2,3

- Wraps to a terminal are parallel with the terminal base and each other.
- Wires are mounted as close to the terminal base as allowed by the insulation.
- Wrapped conductors do not cross over or overlap each other on terminal.
- Calibration parts may be mounted to the tops of hollow terminals, Figure 6-34.

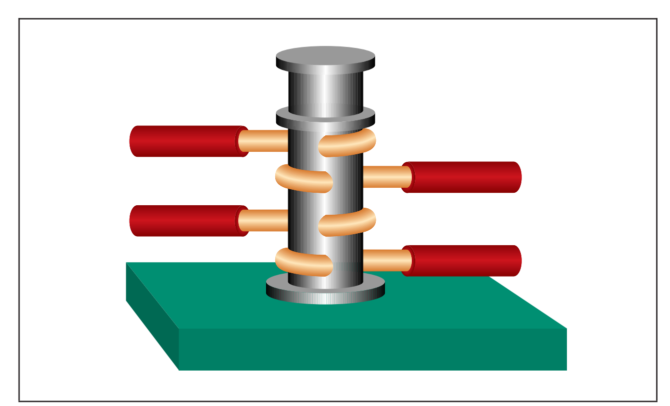


Figure 6-35

Acceptable - Class 1,2
Process Indicator - Class 3

- Wires are not at the base of the terminal, or in contact with the previously installed wire.

Process Indicator - Class 2
Defect - Class 3

- Wrapped conductors cross over or overlap each other on terminal (not shown).

6.7.1 Lead/Wire Placement – Turrets and Straight Pins

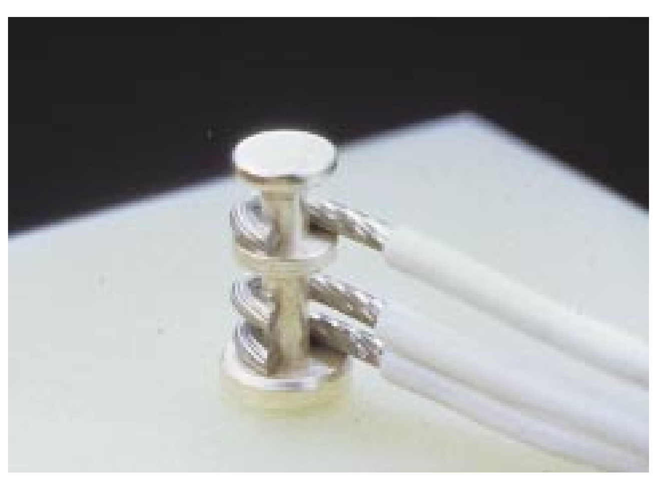


Figure 6-36

Target - Class 1,2,3

- Wraps parallel to each other and to the base.
- Wire mounted against terminal base or previously installed wire.
- On straight pins, the top wire on terminal is one wire diameter below the top of the terminal.
- Wraps are a minimum of 180° and a maximum of 270°.
- Wires and leads mechanically secure to terminals before soldering.

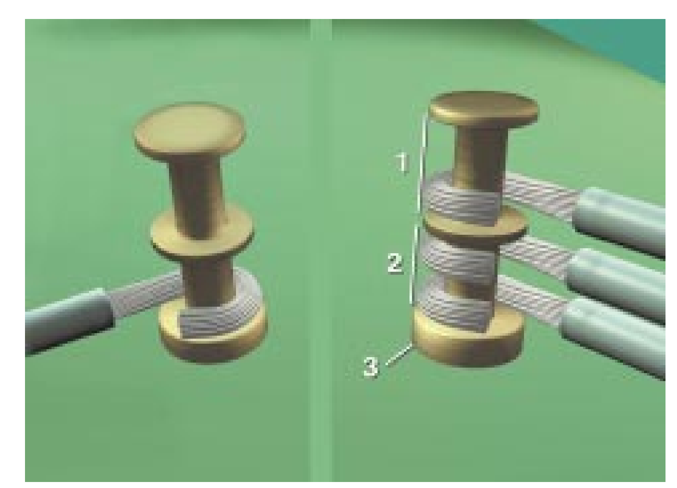


Figure 6-37
1. Upper guide slot
2. Lower guide slot
3. Base

Acceptable - Class 1,2,3

- Wires and leads wrapped a minimum of 180° and do not overlap.

6.7.1 Lead/Wire Placement – Turrets and Straight Pins (cont.)

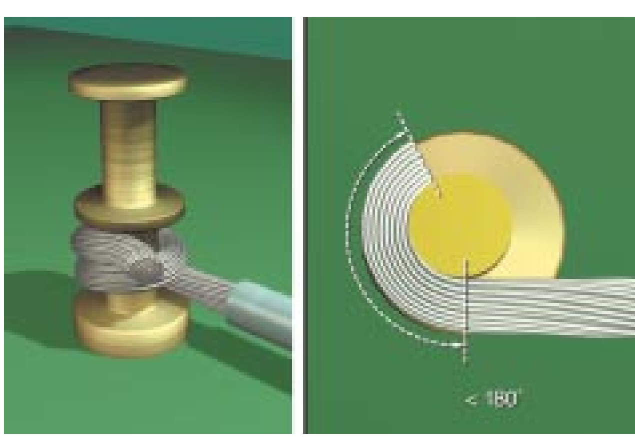


Figure 6-38

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Wire end overlaps itself.

Process Indicator - Class 2

- Wrap for round posts 90° to less than 180° of contact between the wires and the terminal.

Defect - Class 1,2

- Wrap for round posts has less than 90° of contact between the wires and the terminal.

Defect - Class 1,2,3

- Excessively long wire end violates minimum electrical clearance.

Defect - Class 3

- Wrap for round posts has less than 180° of contact between the wires and the terminal.

6.7.2 Lead/Wire Placement – Bifurcated

6.7.2.1 Lead/Wire Placement – Bifurcated – Side Route Attachments




Figure 6-39

Target - Class 1,2,3

- The wire or lead contacts two parallel faces (180° bend) of the terminal post.
- The cut end of the wire contacts the terminal.
- No overlapping of wraps.
- Wires placed in ascending order with largest on the bottom.
- Multiple wire attachments alternate terminal posts.

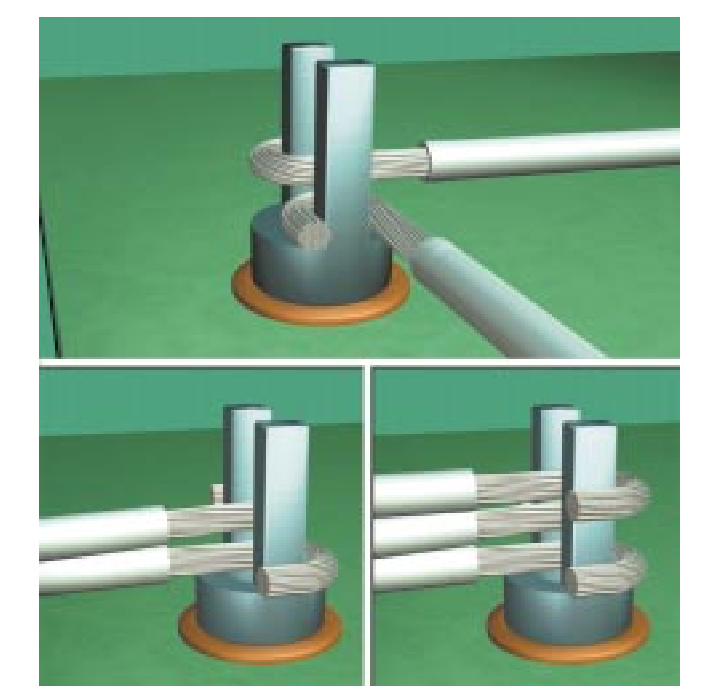


Figure 6-40

Acceptable - Class 1,2,3

- Wire end extends beyond the base of the terminal provided minimum electrical spacing is maintained.
- Wire passes through the slot and makes positive contact with at least one corner of the post.
- No portion of the wrap extends beyond the top of the terminal post.
- If required, wire wrap is at least 90°.

Acceptable - Class 1,2

- Wires/leads 0.75 mm [0.0295 in] or larger in diameter are routed straight through the posts.

Acceptable - Class 3

- Wires/leads 0.75 mm [0.0295 in] or larger in diameter are routed straight through the posts and staked, see 6.7.3.

6.7.2.1 Lead/Wire Placement – Bifurcated – Side Route Attachments (cont.)

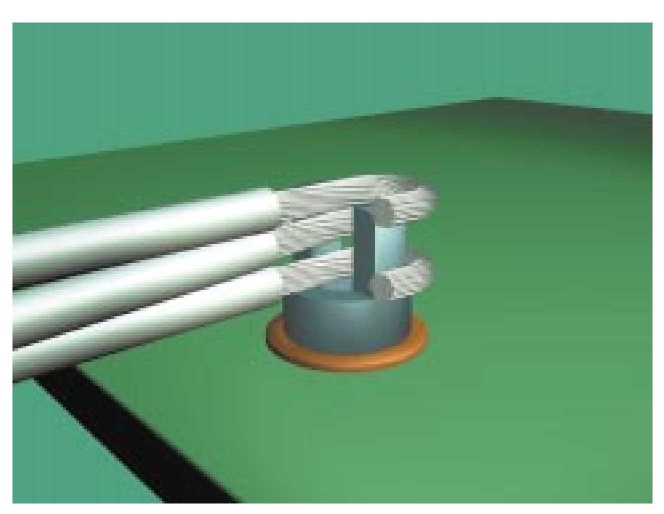


Figure 6-41

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Any portion of the wrap extends beyond the top of terminal post.
- Wire/lead <0.75 mm [0.0295 in] in diameter is wrapped around a post less than 90°.
- Wire end overlaps itself.

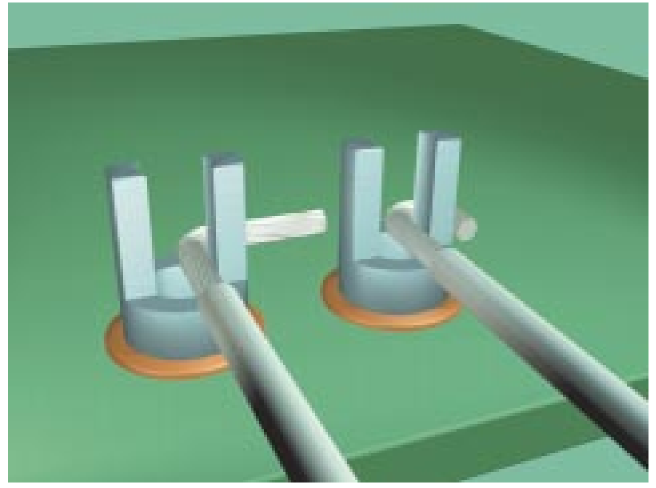


Figure 6-42

Defect - Class 3

- Wire/lead ≥0.75 mm [0.0295 in] in diameter is wrapped less than 90° and is not staked, see 6.7.3.

Defect - Class 1,2,3

- Wire does not pass through slot.
- Wire end violates minimum electrical clearance; see Figure 6-42.

6.7.2.2 Lead/Wire Placement – Bifurcated – Bottom and Top Route Attachments

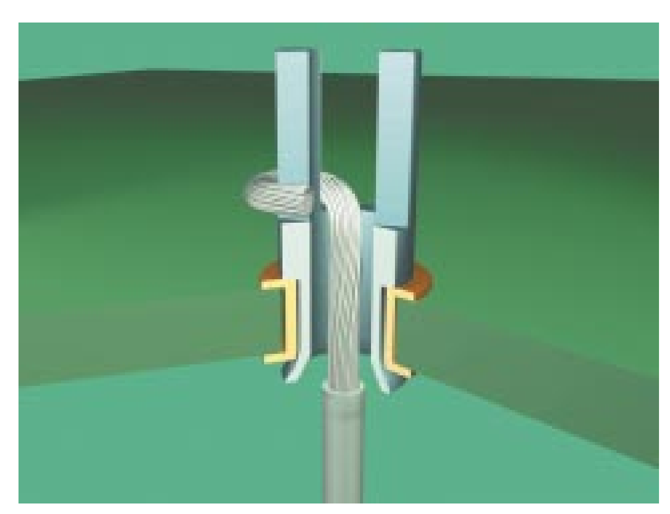


Figure 6-43

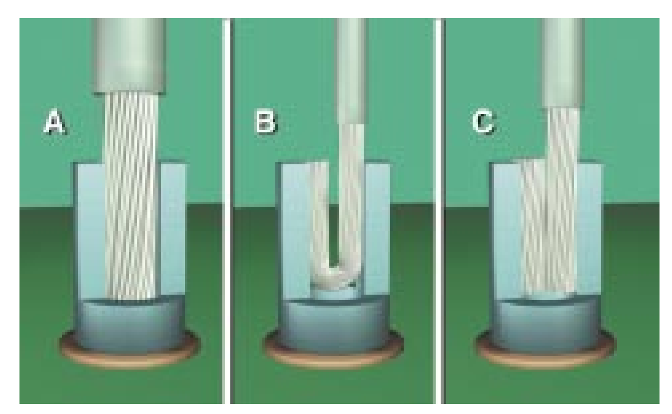


Figure 6-44

Target - Class 1,2,3

- Wire insulation does not enter base or posts of terminal.
- Bottom route wire wrap contacts two parallel sides of post (180°).
- Wire is against base of terminal.
- Top route wire has space between posts filled by using separate filler or bending the wire double (Figure 6-44 B, C).

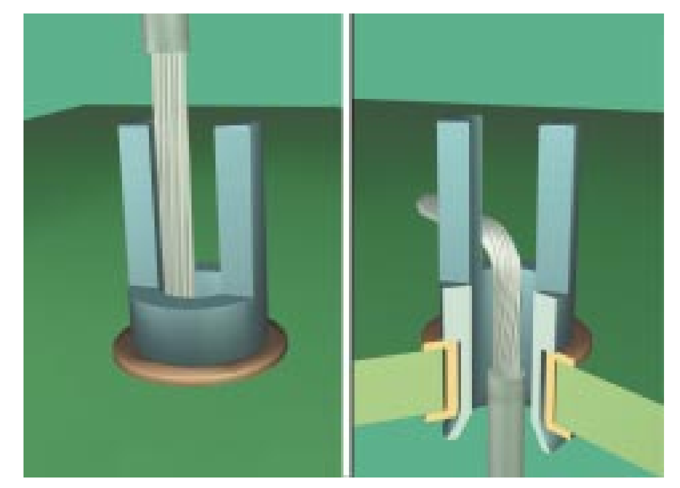


Figure 6-45

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Wire insulation enters base or posts of terminal.
- Top route wire is not supported with filler.
- Bottom route wire not wrapped to terminal base or post with a minimum 90° bend.

6.7.3 Lead/Wire Placement - Staked Wires

As an alternative to wrap requirements of 6.7.2.1 or 6.7.5, the following criteria apply to wires/leads/components that are staked, bonded or otherwise constrained to provide support for the solder connection.

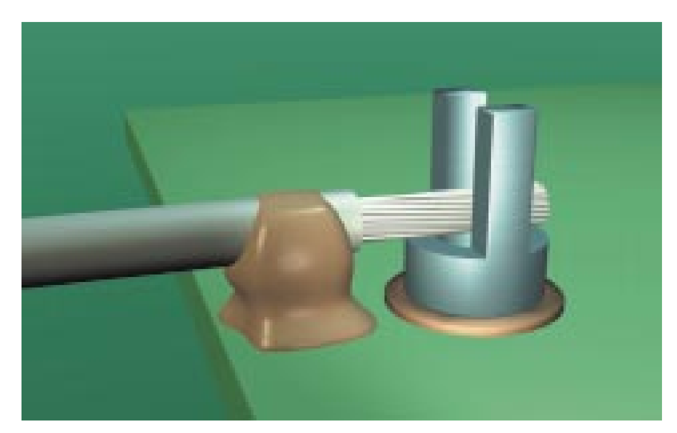


Figure 6-46

Target - Class 1,2,3

- Wire is permanently staked or constrained by a permanent mounting device.
- Wire contacts base of terminal or the previous wire.
- Wire extends through posts of bifurcated terminal.
- Wire extends beyond the eye of pierced/perforated terminals.
- Wire contacts two sides of pierced/perforated terminals.

Acceptable - Class 1
Process Indicator - Class 2

- Wires or leads ≥0.75 mm [0.0295 in] and wrapped less than 90° are not staked.

Defect - Class 1,2

- Wires or leads <0.75 mm [0.0295 in] and wrapped less than 90° are not staked.

Defect - Class 3

- Any straight through wire is not staked.

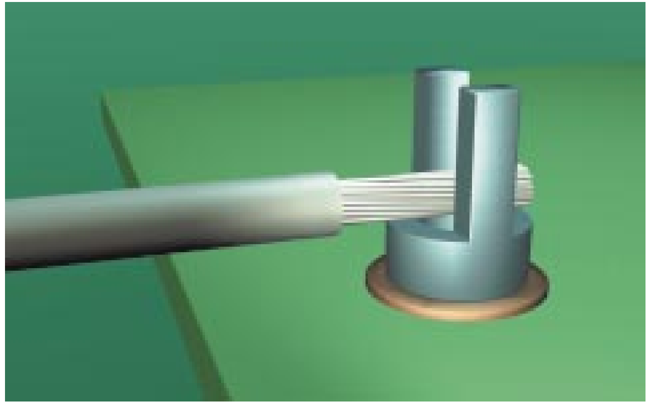


Figure 6-47

Defect - Class 1,2,3

- When required, the wire is not staked or component body not bonded to board or adjacent surface or retained by a mounting device.

6.7.4 Lead/Wire Placement – Slotted



Figure 6-48

Target - Class 1,2,3

- Lead or wire extends completely through slot and is discernible on the exit side.
- Wire is in contact with base of terminal area or previously installed wire.



Figure 6-49

Acceptable - Class 1,2,3

- Lead or wire end is discernible on the exit side of terminal.
- No portion of the wire termination extends above the top of the terminal post.

Note: Wrap is not required on a slotted terminal.

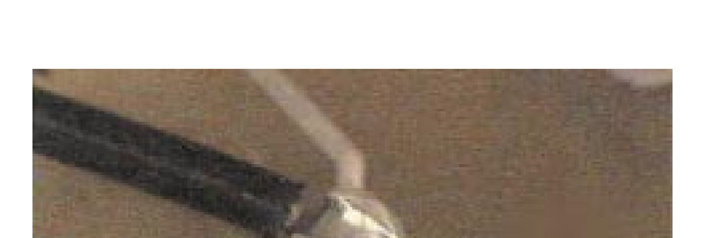


Figure 6-50

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Lead end not discernible on exit side of terminal.
- Wire termination extends above the top of the terminal post.

Defect - Class 1,2,3

- Wire end violates minimum electrical clearance.

6.7.5 Lead/Wire Placement – Pierced/Perforated



Figure 6-51

Target - Class 1,2,3

- Wire passes through the eye of the terminal.
- Wire wrapped to contact two nonadjacent sides of the terminal.

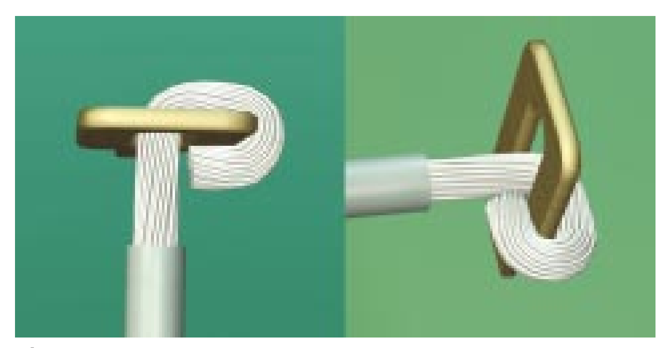


Figure 6-52

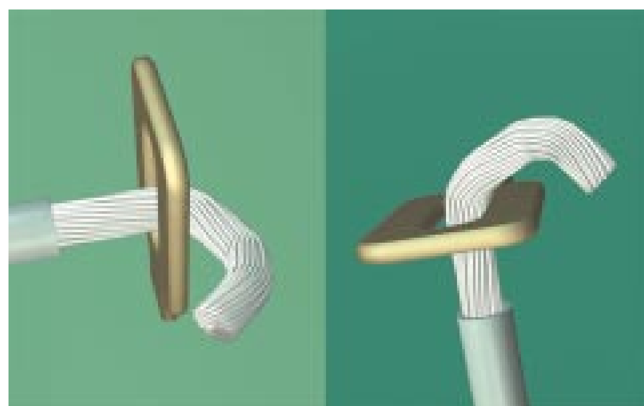


Figure 6-53

Acceptable - Class 1
Defect - Class 2,3

- Wire wrap less than 90° and wire does not contact two nonadjacent sides of the terminal.
- Wire does not pass through the eye of the terminal.

Acceptable - Class 1
Process Indicator - Class 2,3

- Wire end overlaps itself.

Defect - Class 2,3

- Terminal altered to accept oversize wire or wire group.
- Strands not in conformance with Table 6-1.

Defect - Class 1,2,3

- Wire end violates minimum electrical clearance to noncommon conductor (not shown).

6.7.6 Lead/Wire Placement – Hook



Figure 6-54

Target Class 1,2,3

- Wire wrap contacts terminal for a minimum of 180°.
- Minimum of one wire diameter space from end of hook to the closest wire.
- Wires attached within the 180° arc of the hook.
- Wires do not overlap.

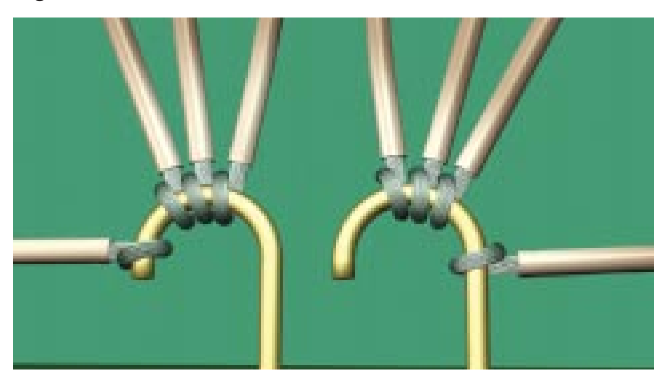


Figure 6-55

Acceptable - Class 1,2,3

- Wire contacts and wraps terminal at least 180°.
- No overlap of wire turns.
- Minimum of one wire diameter space from end of hook to the closest wire.



Figure 6-56

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Wire is wrapped less than one wire diameter from end of hook.
- Wire wrap is less than 180°.
- Wire is attached outside the arc of the hook and less than two lead diameters or 1 mm [0.039 in], whichever is greater, from the base of the terminal.

Acceptable - Class 1
Process Indicator - Class 2,3

- Wire end overlaps itself.

Defect - Class 1,2

- Wire wrap is less than 90°.

Defect - Class 1,2,3

- Wire end violates minimum electrical clearance to noncommon conductor.

6.7.7 Lead/Wire Placement – Solder Cups

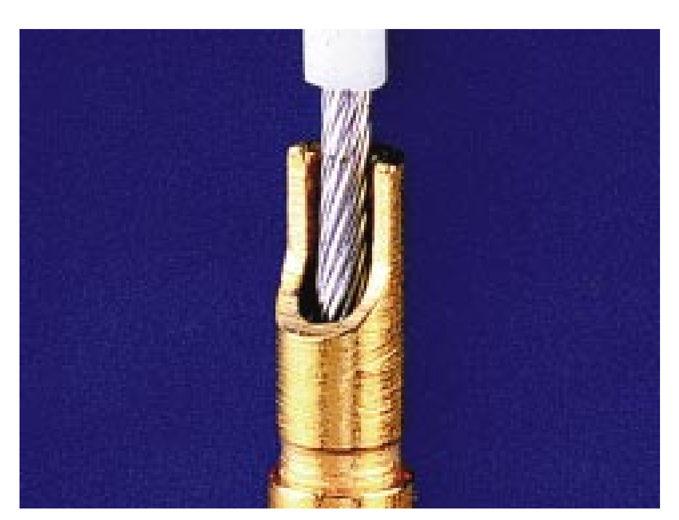
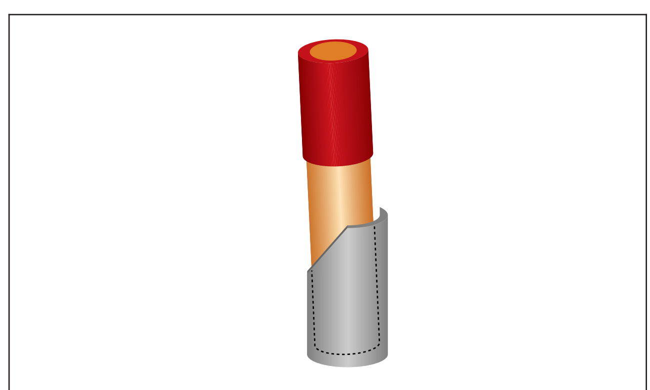

Figure 6-57


Figure 6-58


Figure 6-59

Target - Class 1,2,3

- Solder cups have the wire(s) inserted straight in and contact the back wall or other inserted wires for the full depth of the cup.

Acceptable - Class 1,2,3

- Wire(s) not in contact with back wall do not affect form, fit or function.

Process Indicator - Class 2
Defect - Class 3

- Wire(s) not inserted for full depth of cup.

Defect - Class 2,3

- Solder cup altered to accept oversized wire or wire group.

Defect - Class 1,2,3

- Strands not in conformance with 6.9.3.
- Wires not in contact with back wall interfere with subsequent assembly steps.

6.7.8 Lead/Wire Placement – Series Connected

When three or more terminals are connected by a common bus wire, the end terminals need to meet the required wrap for individual terminals.



Figure 6-60

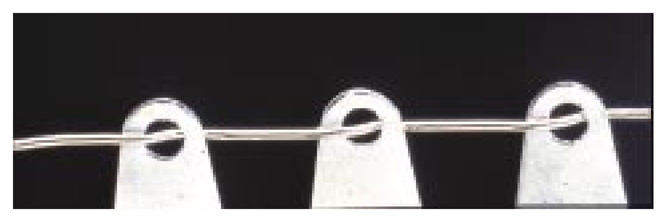


Figure 6-61

Target - Class 1,2,3

- Stress relief radii between each terminal.
- Turrets - Wire contacts base of terminal or a previously installed wire, and wraps around or interweaves each terminal.
- Hooks - Wire wraps 360° around each terminal.
- Bifurcated - Wire passes between posts and contacts base of terminal or previously installed wire.
- Pierced/Perforated - Wire contacts two nonadjacent sides of each terminal.

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Turrets - Wire does not wrap 360° around each inner terminal or is not interwoven between terminals.
- Hooks - Wire wraps less than 360° around inner terminal.
- Bifurcated - Wire does not pass between the posts or is not in contact with the terminal base or a previously installed wire.
- Pierced/Perforated - Wire does not contact two nonadjacent sides of each inner terminal.

Defect - Class 1,2,3

- No stress relief between any two terminals.

6.7.9 Lead/Wire Placement – AWG 30 and Smaller Diameter Wires

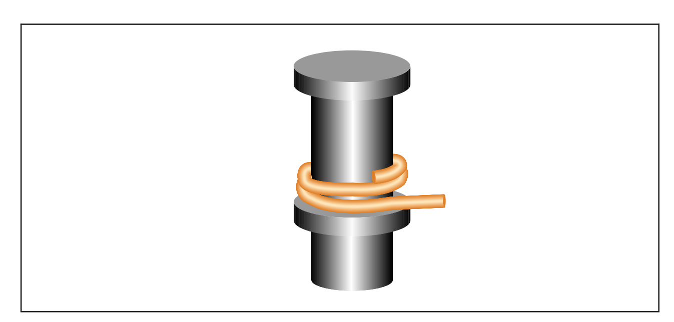


Figure 6-62

Target - Class 1,2,3

- Wire has two wraps (720°) around terminal post.
- Wire does not overlap or cross over itself or other wires terminated on the terminal.

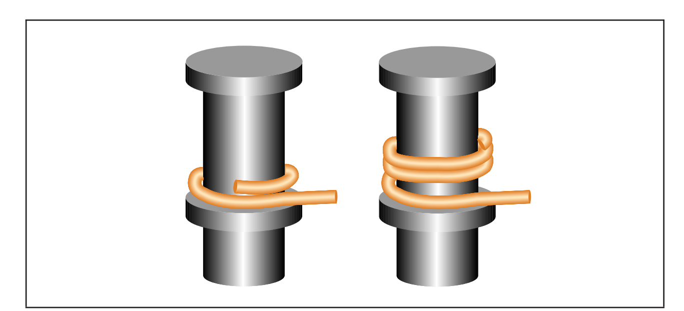


Figure 6-63

Acceptable - Class 1,2,3

- Wire has more than one wrap but less than three.

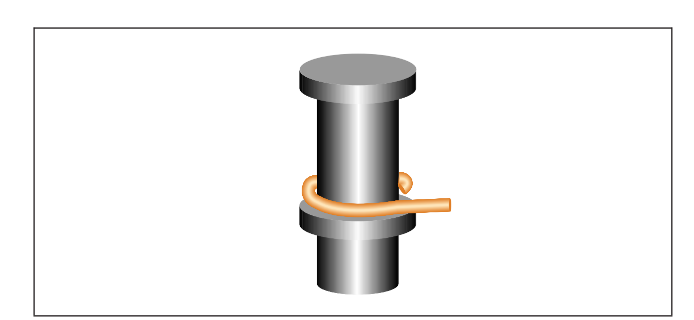


Figure 6-64

Defect - Class 2

- Wire has less than 180° wrap.

Process Indicator - Class 2
Defect - Class 3

- Wire has less than one wrap around terminal.

6.8 Insulation

6.8.1 Insulation – Clearance



Figure 6-65

Target - Class 1,2,3

- There is an insulation clearance (C) of one wire diameter (D) between the end of the insulation and the solder fillet.

Figure 6-66

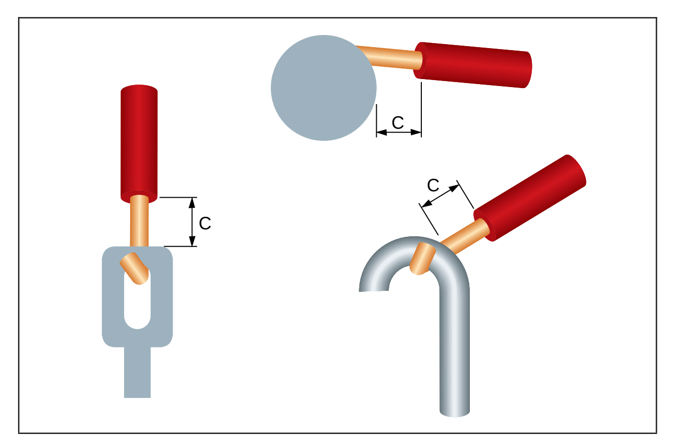
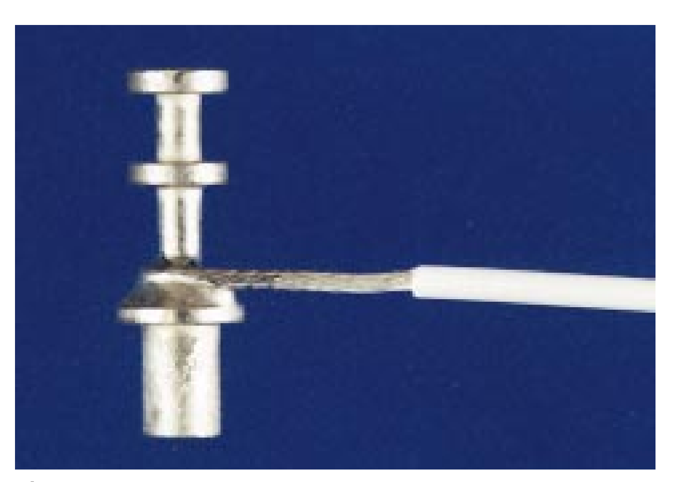


Figure 6-67

Acceptable - Class 1,2,3

- The insulation clearance (C) is two wire diameters or less including insulation or 1.5 mm [0.0591 in] (whichever is greater).
- Insulation clearance (C) does not permit violation of minimum electrical clearance to adjacent conductors.
- The insulation is in contact with the solder but does not interfere with formation of an acceptable connection.

6.8.1 Insulation – Clearance (cont.)


Figure 6-68

Acceptable - Class 1

- Exposed bare wire providing there is no danger of violating minimum electrical clearance to adjacent circuitry when the wire is moved.

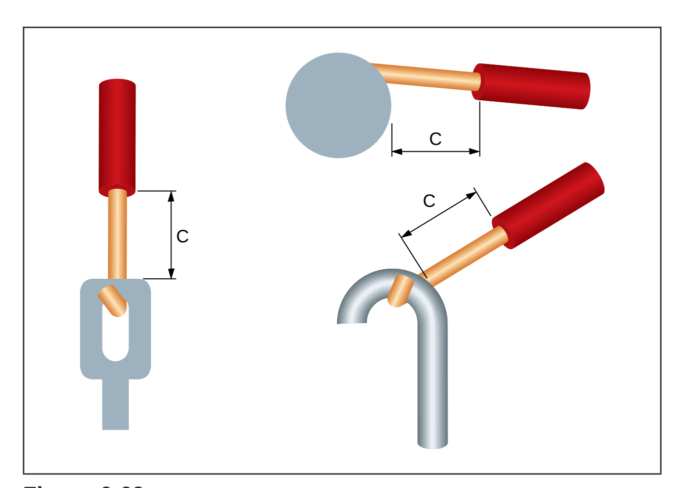


Figure 6-69

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- The insulation clearance (C) is greater than two wire diameters including insulation or 1.5 mm [0.0591 in], whichever is greater.

Defect - Class 1,2,3

- Insulation clearance (C) permits violation of minimum electrical clearance to adjacent conductors.
- Insulation interferes with formation of the solder connection.

6.8.2 Insulation – Damage

6.8.2.1 Insulation – Damage – Presolder

Coatings added over insulation base material such as resin coatings over polyimide are not considered to be part of the insulation and these criteria are not intended to be applicable to those coatings.



Figure 6-70

Target - Class 1,2,3

- Insulation has been trimmed neatly with no signs of pinching, pulling, fraying, discoloration, charring or burning.

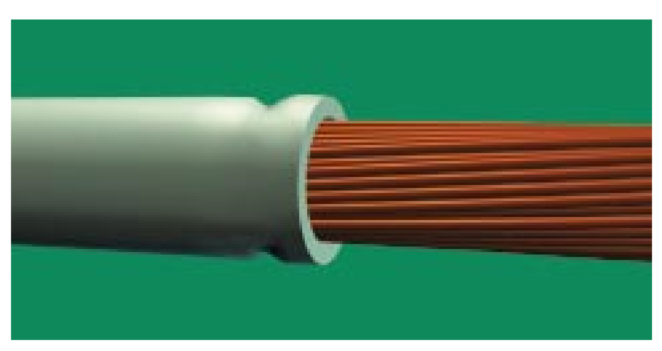


Figure 6-71

Acceptable - Class 1,2,3

- A slight, uniform impression in the insulation from the gripping of mechanical strippers.
- Chemical solutions, paste, and creams used to strip solid wires do not cause degradation to the wire.
- Slight discoloration of insulation resulting from thermal processing is permissible, provided it is not charred, cracked or split.

6.8.2.1 Insulation – Damage – Presolder (cont.)


Figure 6-72

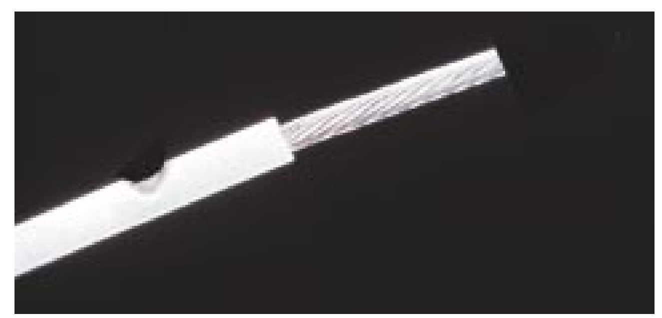
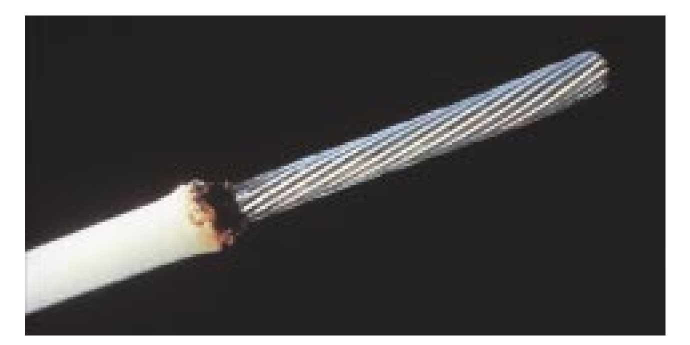

Figure 6-73


Figure 6-74


Figure 6-75

Defect - Class 1,2,3

- Any cuts, breaks, cracks or splits in insulation (not shown).
- Insulation is melted into the wire strands (not shown).
- Insulation thickness is reduced by more than 20% (Figures 6-72, 6-73).
- Uneven or ragged pieces of insulation (frays, tails, and tags) are greater than 50% of the insulation outside diameter or 1 mm [0.039 in] whichever is more (Figure 6-74).
- Insulation is charred (Figure 6-75).

6.8.2.2 Insulation – Damage – Post-Solder

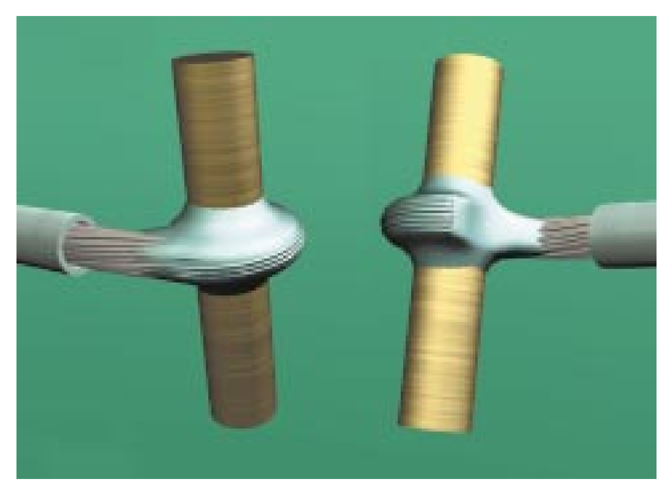


Figure 6-76

Target - Class 1,2,3

- Insulation is not melted, charred or otherwise damaged from the soldering process.

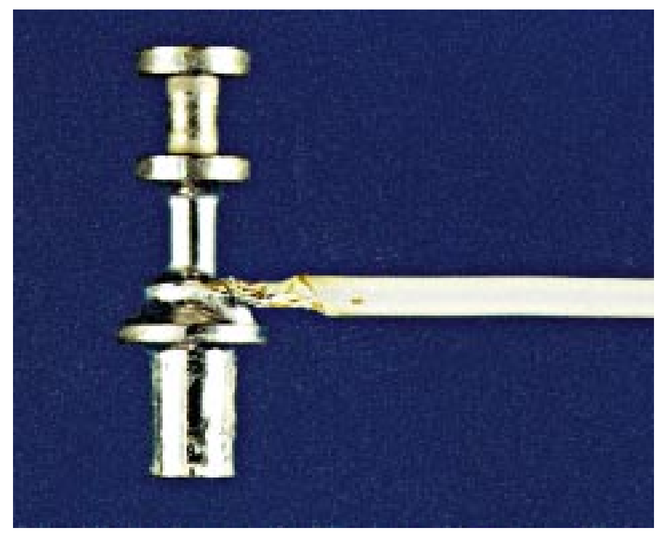


Figure 6-77

Acceptable - Class 1,2,3

- Slight melting of insulation.



Figure 6-78

Defect - Class 1,2,3

- Insulation charred.
- Solder connection contaminated by burnt or melted insulation.

6.8.3 Insulation – Flexible Sleeve

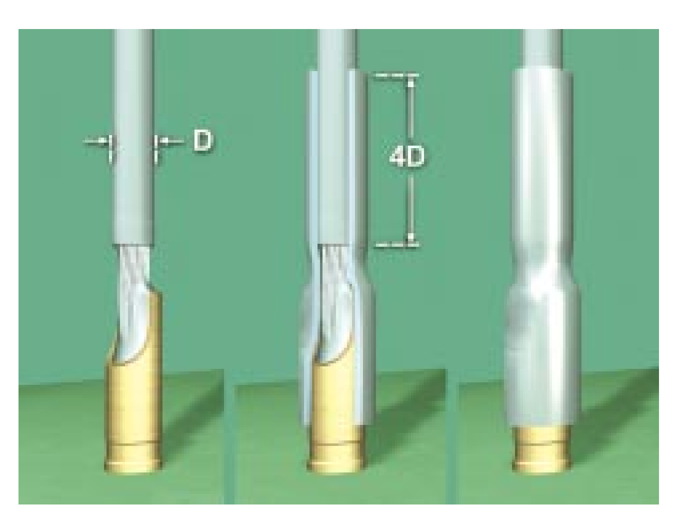


Figure 6-79

Target - Class 1,2,3

- Insulation sleeving overlaps the connector terminal and extends over the wire insulation four wire diameters (D).
- Insulation sleeving is one wire diameter (D) from the point where the connector terminal enters the connector insert.

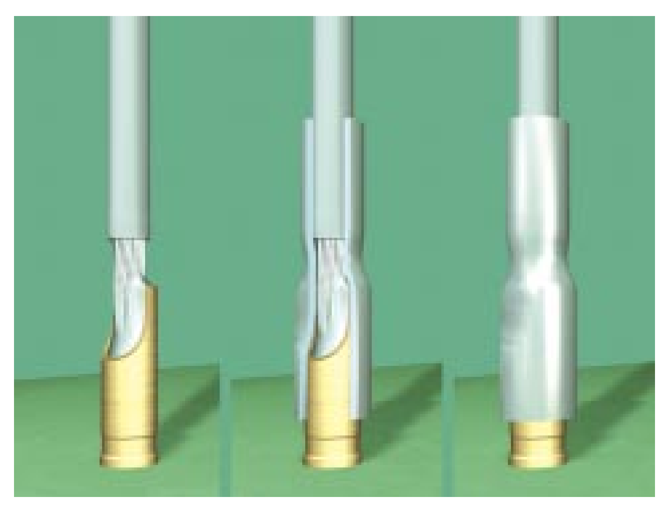


Figure 6-80

Acceptable - Class 1,2,3

- Insulation sleeving overlaps the connector terminal and the wire insulation by a minimum of two wire diameters.
- Insulation sleeving is more than 50% wire diameter and not more than two wire diameters from the point where the connector terminal enters the connector insert.

6.8.3 Insulation – Flexible Sleeve (cont.)

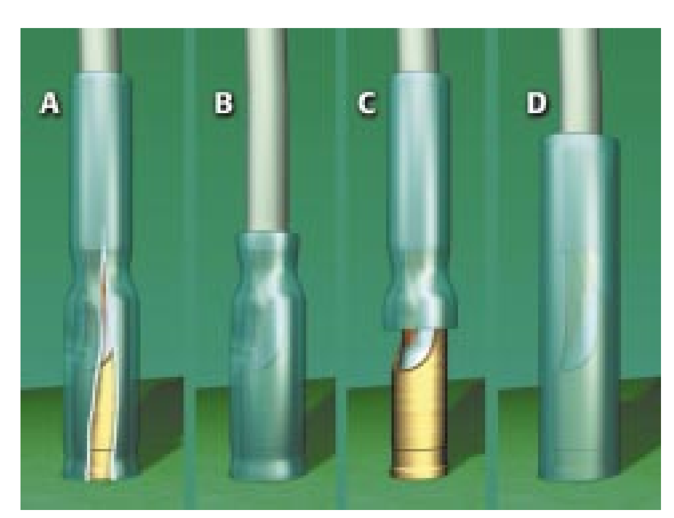


Figure 6-81

Defect - Class 2,3

- Insulation sleeving is damaged, e.g., split (A), charred (not shown).
- Insulation sleeving overlaps the wire insulation by less than two wire diameters (B).
- Insulation sleeving is more than two wire diameters from the point where the connector terminal enters the connector insert (C).
- Insulation sleeve is loose on the terminal (could slide or vibrate off, exposing more than the allowed amount of conductor or terminal) (D).
- Insulation sleeving prevents movement of floating contact in the insert, when movement is required.

6.9 Conductor

Applies to multistranded wires; see 7.1.2.3 for lead damage requirements applicable to single strand wires.

6.9.1 Conductor – Deformation

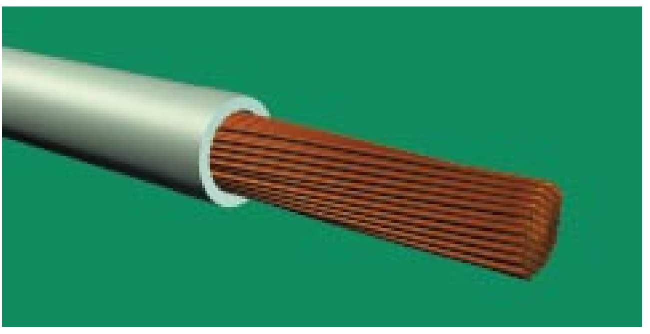


Figure 6-82

Target - Class 1,2,3

- Strands are not flattened, untwisted, buckled, kinked or otherwise deformed.

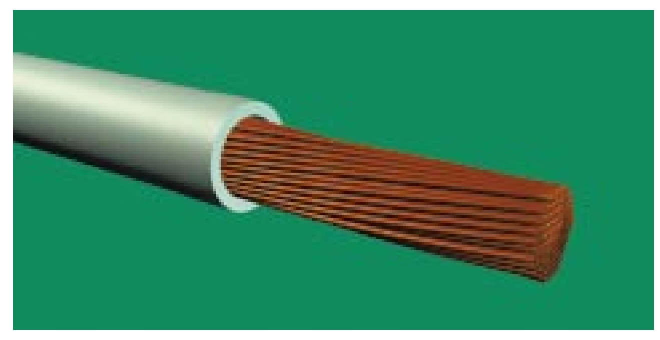


Figure 6-83

Acceptable - Class 1,2,3

- Where strands were straightened during the insulation removal, they have been restored to approximate the original spiral lay of the wire.
- Wire strands are not kinked.

Acceptable - Class 1
Defect - Class 2,3

- The general spiral lay of the strands has not been maintained.

6.9.2 Conductor – Strand Separation (Birdcaging)

Wire strands disturbed during insulation removal process should be restored to approximate their original lay.

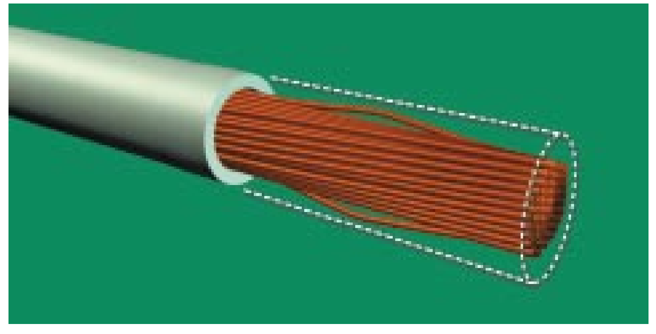


Figure 6-84

Target - Class 1, 2, 3

- Original lay of strands is not disturbed.

Acceptable - Class 1, 2, 3

- Wire strands have separation (birdcaging) but do not exceed:
  - One strand diameter.
  - Do not extend beyond wire insulation outside diameter.

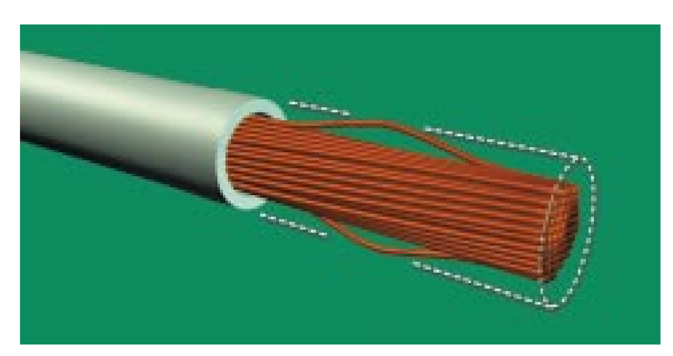


Figure 6-85

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Wire strands have separation exceeding one strand diameter but do not extend beyond wire insulation outside diameter.

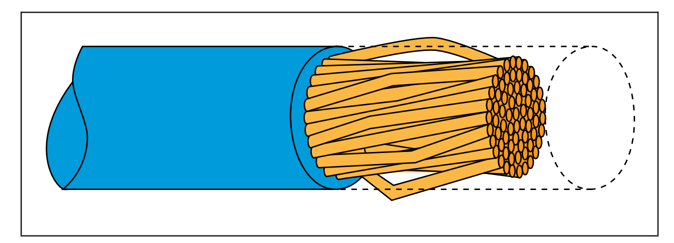


Figure 6-86

Acceptable - Class 1
Defect - Class 2,3

- Wire strands extend beyond wire insulation outside diameter.

6.9.3 Conductor – Damage

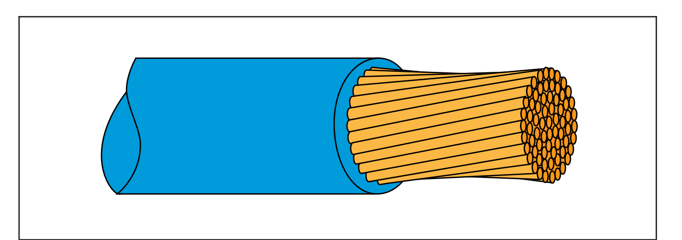


Figure 6-87

Target - Class 1,2,3

- Wires are not scraped, nicked, cut, flattened, scored, or otherwise damaged.

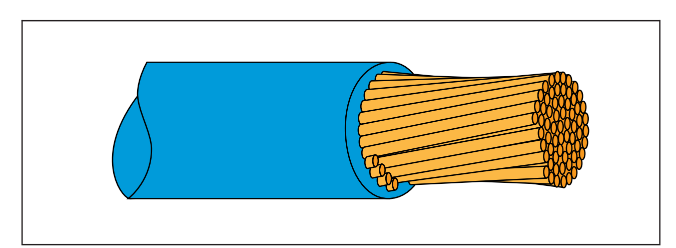


Figure 6-88

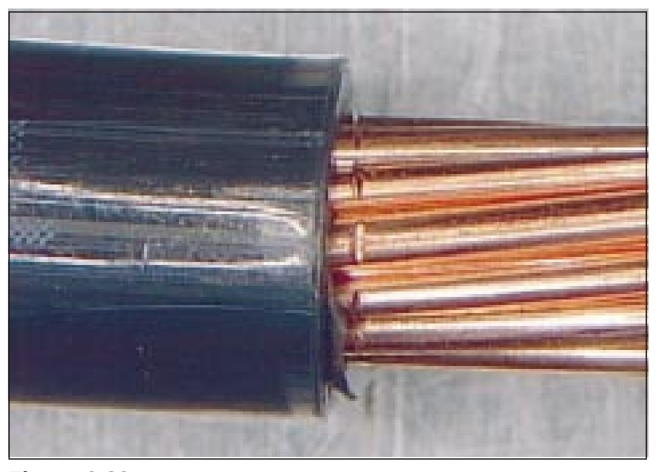


Figure 6-89

Acceptable - Class 1
Process Indicator - Class 2,3

- Strands cut, broken, scraped or severed if the number of damaged or broken strands in a single wire does not exceed the limits in Table 6-1.

Defect - Class 1,2,3

- The number of damaged (scraped, nicked or severed) strands in a single wire exceeds the limits in Table 6-1.

Table 6-1 Allowable Strand Damage

Number of Strands	Maximum allowable strands scraped, nicked or severed for Class 1,2	Maximum allowable strands scraped, nicked or severed for Class 3 for wires that will not be tinned before installation	Maximum allowable strands scraped, nicked or severed for Class 3 for wires that will be tinned prior to installation
Less than 7	0	0	0
7-15	1	0	1
16-25	3	0	2
26-40	4	3	3
41-60	5	4	4
61-120	6	5	5
121 or more	6%	5%	5%

Note 1: No damaged strands for wires used at a potential of 6 kV or greater.
Note 2: For plated wires, a visual anomaly that does not expose basis metal is not considered to be strand damage.

6.10 Terminals – Solder

Unless otherwise stated for a specific terminal type, the following are general requirements for all terminals:

Target - Class 1,2,3

- 100% solder fillet around wire/lead and terminal interface (full extent of wrap).
- Solder wets the wire/lead and terminal and forms a discernible fillet feathering out to a smooth edge.
- Wire/lead is clearly discernible in the solder connection.

Acceptable - Class 1,2,3

- Solder fillet at least 75% of the circumference of the wire/lead and terminal interface.
- Height of solder is greater than 75% of wire diameter in the wire to post contact area.

Acceptable - Class 1
Process Indicator - Class 2,3

- Wire/lead not discernible in solder connection.

Defect - Class 1,2

- Depression of solder between the post and the wrap of the wire is greater than 50%.

Defect - Class 3

- Depression of solder between the post and the wrap of the wire is greater than 25%.

Defect - Class 1,2,3

- Solder fillet is less than 75% of the circumference of the wire/lead and terminal interface.

6.10.1 Solder – Turret



Figure 6-90



Figure 6-91

Target - Class 1,2,3

- Lead outline is discernible, smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.

Acceptable - Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped 180° or more.
- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.



Figure 6-92

Defect - Class 1,2,3

- Poor wetting.
- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.
- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more.

6.10.2 Terminals – Solder – Bifurcated

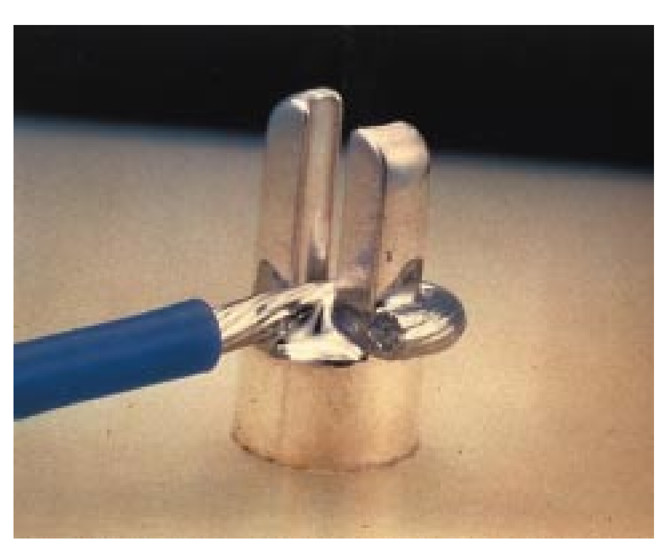


Figure 6-93



Figure 6-94

Target - Class 1,2,3

- Lead outline is discernible; smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.

6.10.2 Terminals – Solder – Bifurcated (cont.)



Figure 6-95



Figure 6-96

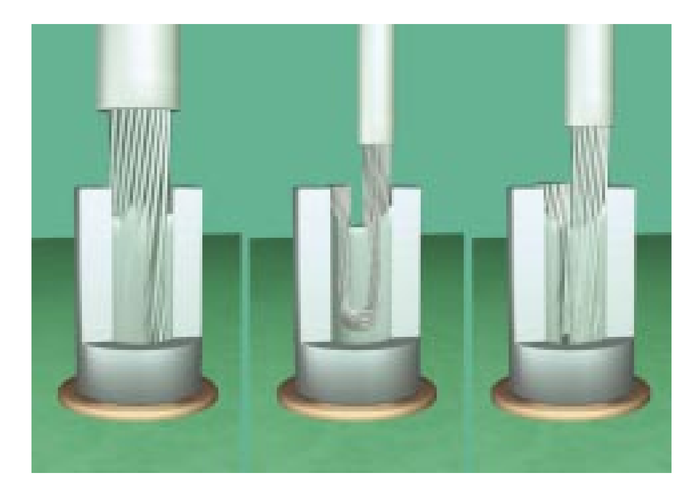


Figure 6-97

Acceptable - Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped 180° or more.
- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.
- Solder is 75% of the height of the terminal post for top-route wires.

6.10.2 Terminals – Solder – Bifurcated (cont.)

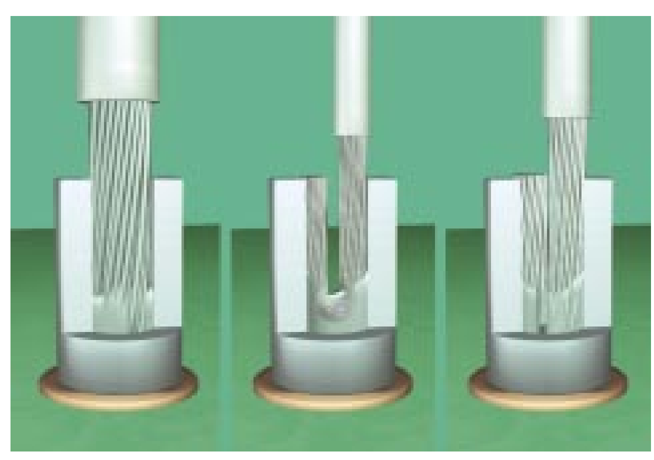


Figure 6-98

Defect - Class 1,2,3

- Solder is less than 75% of the height of the terminal post for top-route wires.
- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.
- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more.

6.10.3 Terminals – Solder – Slotted

Solder should form a fillet with that portion of the lead or wire that is in contact with the terminal. Solder may completely fill the slot but should not be built up on top of the terminal. The lead or wire should be discernible in the terminal.



Figure 6-99

Target - Class 1,2,3

- Solder forms a fillet with that portion of the lead or wire that is in contact with the terminal.
- There is visible insulation clearance.



Figure 6-100

Acceptable - Class 1,2,3

- Solder fills terminal slot.
- Lead or wire end is discernible in the solder on the exit side of terminal.



Figure 6-101

Defect - Class 1,2,3

- Wire or lead end is not discernible.
- Fillet not formed with 100% of the portion of the wire that is in contact with the terminal (not shown).

6.10.4 Terminals – Solder – Pierced Tab

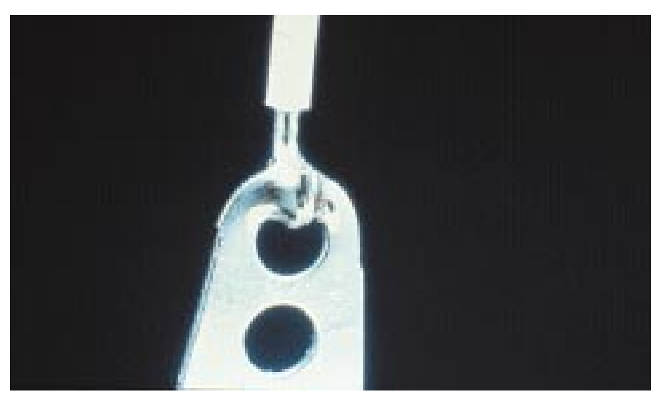


Figure 6-102

Target - Class 1,2,3

- Lead outline is discernible; smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.



Figure 6-103



Figure 6-104

Acceptable - Class 1,2,3

- Solder fillet joins the wire to the terminal for at least 75% of the wire and terminal interface for wraps of 180° or more.
- Solder fillet joins the wire to the terminal for 100% of the wire and terminal interface for wraps <180°.



Figure 6-105

Defect - Class 1,2,3

- Solder dewetted from terminal.
- Solder contact angle greater than 90°.
- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.
- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more.

6.10.5 Terminals – Solder – Hook/Pin



Figure 6-106

Target - Class 1,2,3

- Lead outline is discernible; smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.



Figure 6-107

Acceptable - Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped 180° or more.
- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.



Figure 6-108



Figure 6-109

Defect - Class 1,2,3

- Solder contact angle greater than 90°.
- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.
- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more.

6.10.6 Terminals – Solder – Solder Cups

These criteria are applicable to either solid or stranded wire, single or multiple wires.

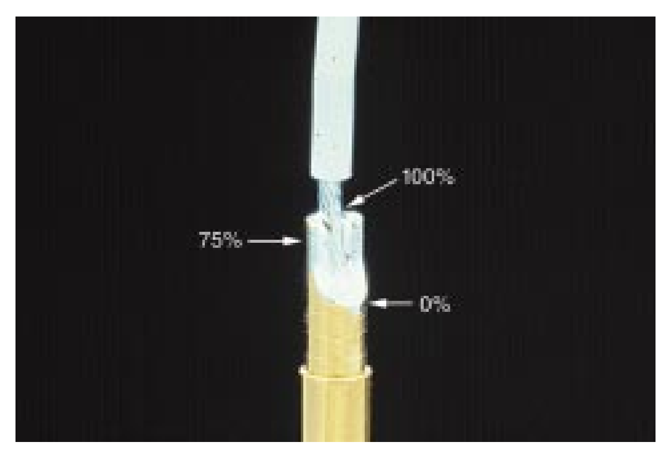


Figure 6-110

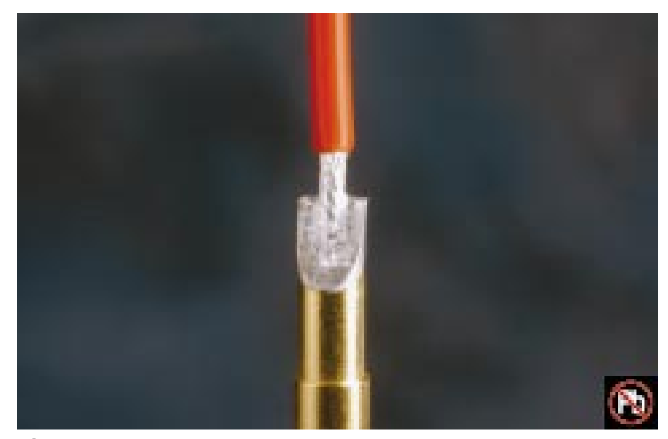
Target - Class 1,2,3

- Solder wets the entire inside of the cup.
- Solder fill is 100%.


Figure 6-111

Acceptable - Class 1,2,3

- Thin film of solder on the outside of the cup.
- Solder fill 75% or more.
- Solder buildup on the outside of the cup, as long as it does not affect form, fit or function.


Figure 6-112

6.10.6 Terminals – Solder – Solder Cups (cont.)

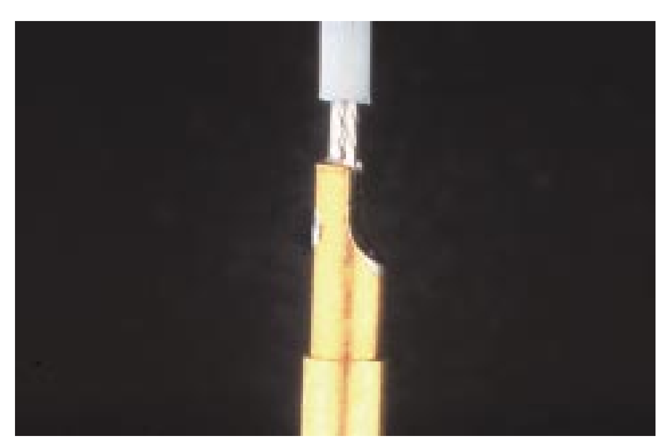


Figure 6-113



Figure 6-114

Defect Class 1,2,3

- Solder vertical fill less than 75%.
- Solder buildup on outside of the cup negatively affects form, fit or function.



Figure 6-115

6.11 Conductor – Damage – Post-Solder



Figure 6-116

Target - Class 1,2,3

- No birdcaging.

Acceptable - Class 1,2,3

- Wire strands have separation (birdcaging) (see Figure 6-84) but do not exceed the lesser of:
  - One strand diameter.
  - Do not extend beyond wire insulation outside diameter.



Figure 6-117

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Wire strands have separation exceeding one strand diameter but do not extend beyond wire insulation outside diameter.

Defect - Class 2, 3

- Wire strands are birdcaged beyond wire insulation outside diameter.

7 Through-Hole Technology

This section includes hardware, adhesive, forming, mounting, termination and soldering criteria for through-hole installation.

The placement of any component on the electronic assembly does not prevent the insertion or removal of any hardware (tool clearance included) used to mount the assembly.

Minimum spacing between installed hardware and the conducting land, component leads or uninsulated components depends on specified voltage and is not less than the specified minimum electrical clearance, see 1.4.5.

Bonding material is sufficient to hold the part but does not encapsulate and cover component identification.

Visual inspection includes part identification, assembly sequence, and damage to hardware, component, or board.

In addition to the criteria in this section, solder connections must meet the criteria of Section 5.

The following topics are addressed in this section:

7.1 Component Mounting

7.1.1 Component Mounting – Orientation

This section covers acceptability requirements for the installation, location, and orientation of components and wires mounted onto printed boards.

Criteria are given for only the actual mounting or placement of components or wires on electronic assemblies and to standoff terminals. Solder is mentioned where it is an integral part of the placement dimensions, but only as related to those dimensions.

Inspection usually starts with a general overall view of the electronic assembly, then follows each component/wire to its connection, concentrating on the lead into the connection, the connection and the tail end of the lead/wire leaving the connection. The wire/lead protrusion step for all lands should be saved for last so that the board can be flipped over and all connections checked together.

7.1.1.1 Component Mounting – Orientation – Horizontal

Additional criteria for horizontal mounting of axial leaded components are provided in clauses 7.4.1 (unsupported holes) and 7.5.1 (supported holes).

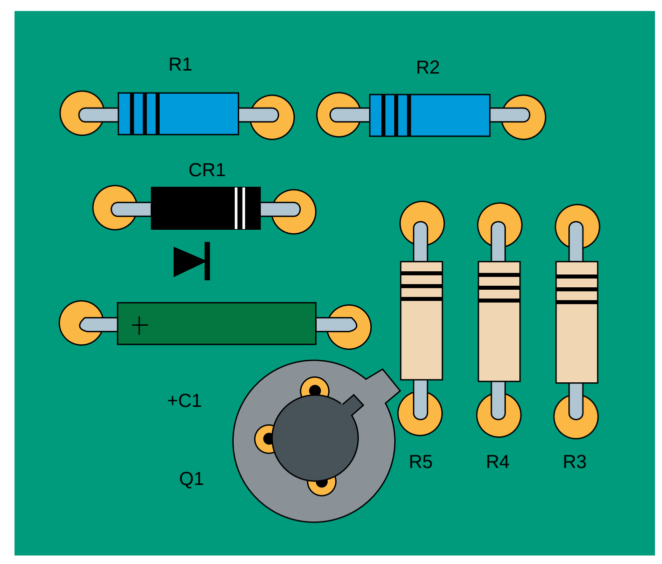


Figure 7-1

Target - Class 1,2,3

- Components are centered between their lands.
- Component markings are discernible.
- Nonpolarized components are oriented so that markings all read the same way (left-to-right or top-to-bottom).

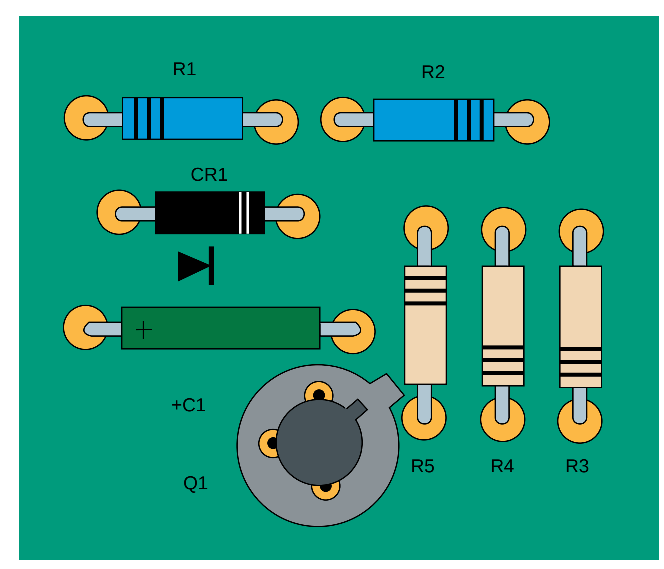


Figure 7-2

Acceptable - Class 1,2,3

- Polarized and multilead components are oriented correctly.
- When hand formed and hand-inserted, polarization symbols are discernible.
- All components are as specified and terminate to correct lands.
- Nonpolarized components are not oriented so that markings all read the same way (left-to-right or top-to-bottom).

7.1.1.1 Component Mounting – Orientation – Horizontal (cont.)

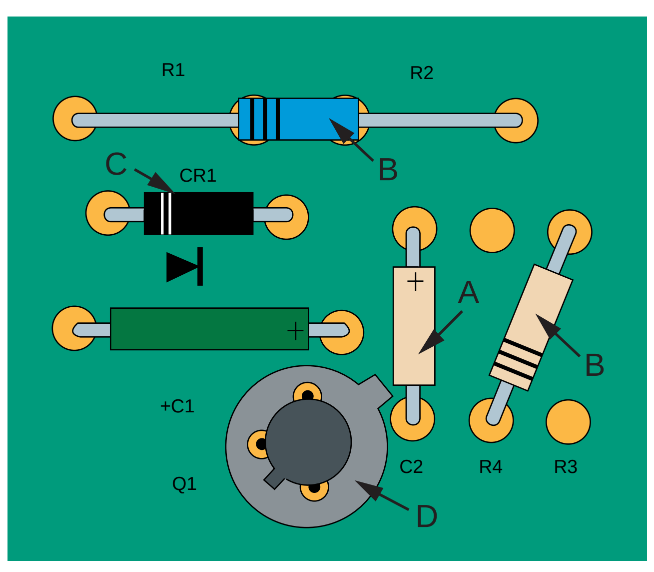


Figure 7-3

Defect - Class 1,2,3

- Component is not as specified (wrong part) (A).
- Component not mounted in correct holes (B).
- Polarized component mounted backwards (C).
- Multileaded component not oriented correctly (D).

7.1.1.2 Component Mounting – Orientation – Vertical

Additional criteria for vertical mounting of axial leaded components are provided in clauses 7.4.2 (unsupported holes) and 7.5.2 (supported holes).

In the examples in Figures 7-4 through 7-6, the arrows printed on the black capacitor casing are pointing to the negative end of the component.

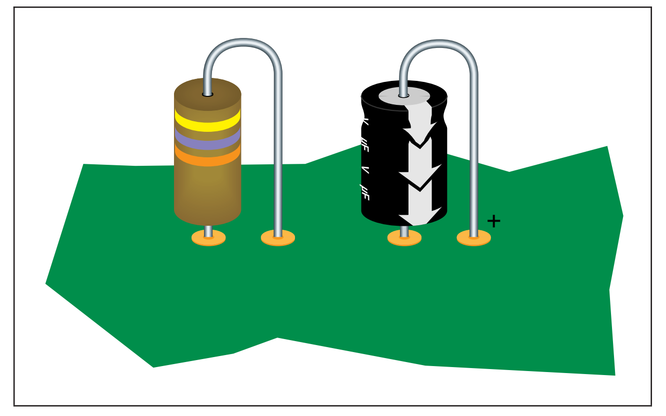


Figure 7-4

Target - Class 1,2,3

- Nonpolarized component markings read from the top down.
- Polarized markings are located on top.

Figure 7-5

Acceptable - Class 1,2,3

- Polarized part is mounted with a long ground lead.
- Polarized marking hidden.
- Nonpolarized component markings read from bottom to top.

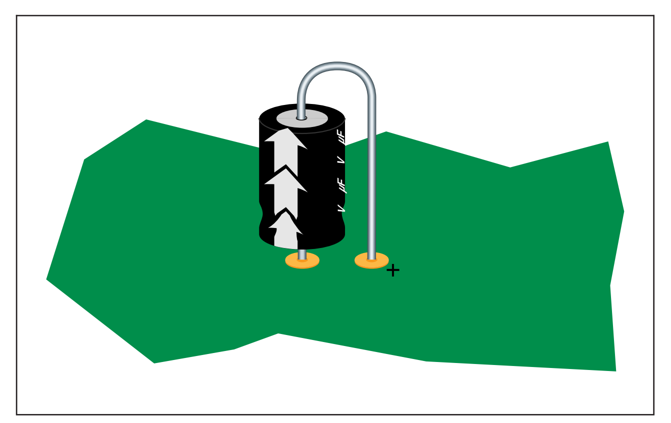


Figure 7-6

Defect - Class 1,2,3

- Polarized component is mounted backwards.

7.1.2 Component Mounting – Lead Forming

7.1.2.1 Component Mounting – Lead Forming – Bends

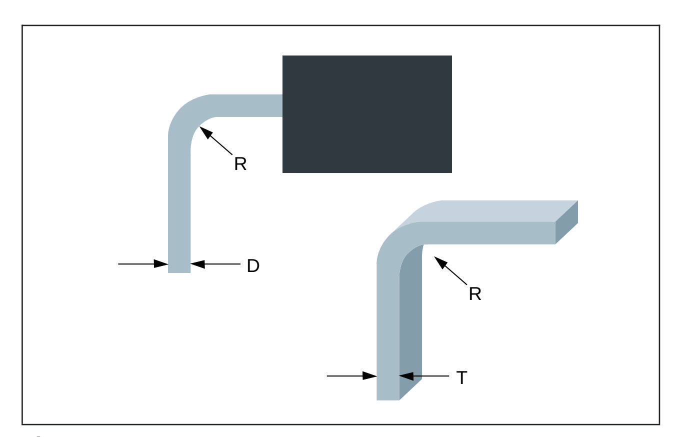


Figure 7-7

Table 7-1 Minimum Inside Bend Radius

Lead Diameter (D) or Thickness (T)	Minimum Inside Bend Radius (R)
<0.8 mm [0.031 in]	1 D/T
0.8 mm [0.031 in] to 1.2 mm [0.0472 in]	1.5 D/T
>1.2 mm [0.0472 in]	2 D/T

Note: Rectangular leads use thickness (T).

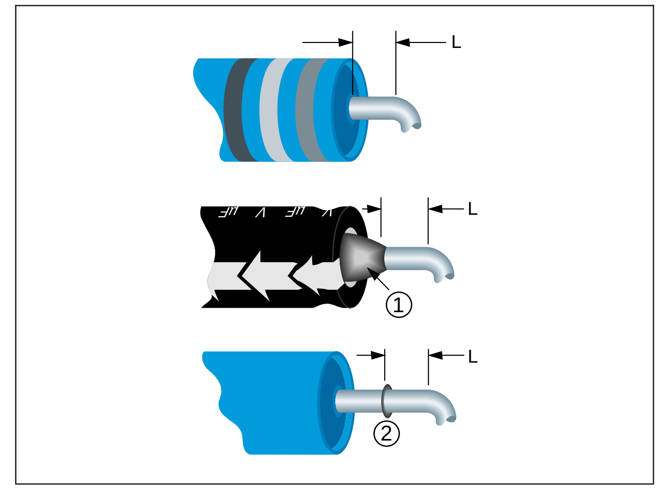


Figure 7-8
1. Solder bead
2. Weld

Acceptable - Class 1,2,3

- Leads for through-hole mounting extend at least one lead diameter or thickness but not less than 0.8 mm [0.031 in] from the body, solder bead, or lead weld.
- Lead is not kinked or cracked.
- The minimum inside bend radius of component leads meets requirements of Table 7-1.

7.1.2.1 Component Mounting – Lead Forming – Bends (cont.)

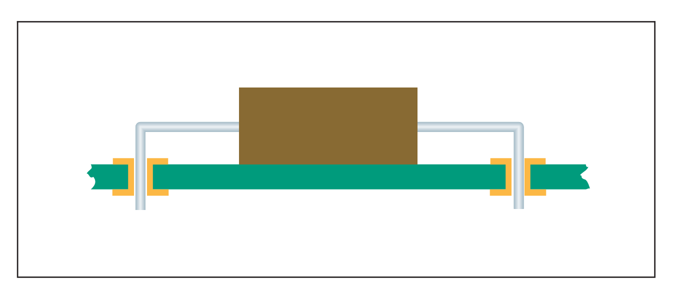


Figure 7-9

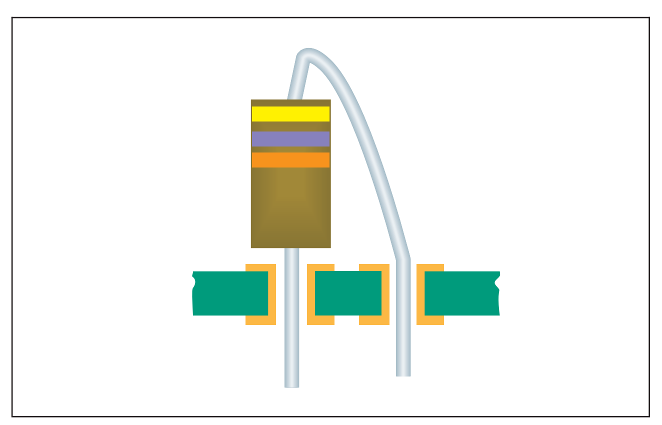


Figure 7-10

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- The inside bend radius does not meet requirements of Table 7-1.



Figure 7-11

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Lead bend of through-hole mounted component is less than one lead diameter or 0.8 mm [0.031 in], whichever is less, from the component body, solder bead or component body lead seal.

Defect - Class 1,2,3

- Fractured lead weld, solder bead, or component body lead seal.

7.1.2.2 Component Mounting – Lead Forming – Stress Relief

Components are mounted in any one or a combination of the following configurations:

- In a conventional manner utilizing 90° (nominal) lead bends directly to the mounting hole.
- With camel hump bends. Configuration incorporating a single camel hump may have the body positioned off-center.
- Other configurations may be used with agreement of the customer or where design constraints exist.

Loop bends may be used if the location of the mounting holes prevent the use of a standard bend and if there is no possibility of shorting the lead to any adjacent component lead or conductor. Use of loop bends may impact circuit impedance, etc., and needs to be approved by design engineering.

Prepped components with stress bends as shown in Figure 7-13 usually cannot meet the maximum spacing requirements of a straight-legged vertical - radial leaded component, see 7.1.6. Maximum space between component and board surface is determined by design limitations and product use environments. The component preparation equipment and manufacturer's suggested component lead bend specifications and capabilities determine limitation. This may require change in tooling to meet requirements for end use.

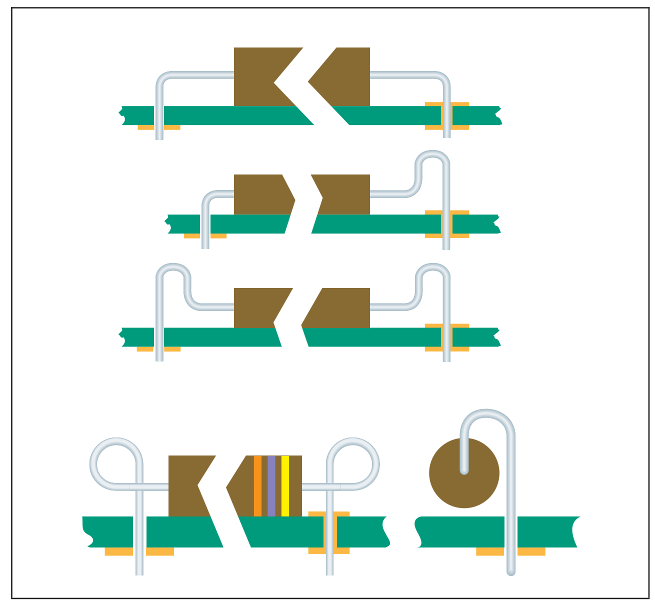


Figure 7-12

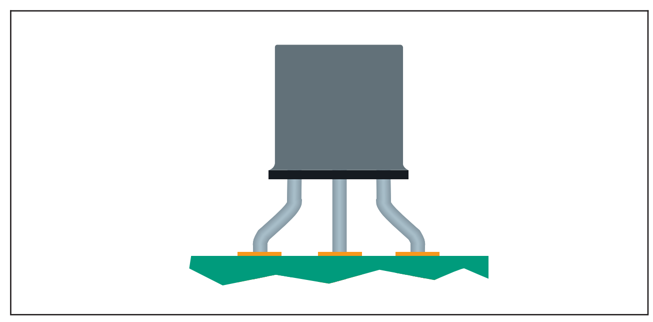


Figure 7-13

Acceptable Class 1,2,3

- Leads are formed to provide stress relief.
- Component lead exiting component body is approximately parallel to major body axis.
- Component lead entering hole is approximately perpendicular to board surface.
- Component centering may be offset as a result of the type of stress relief bend.

7.1.2.2 Component Mounting – Lead Forming – Stress Relief (cont.)

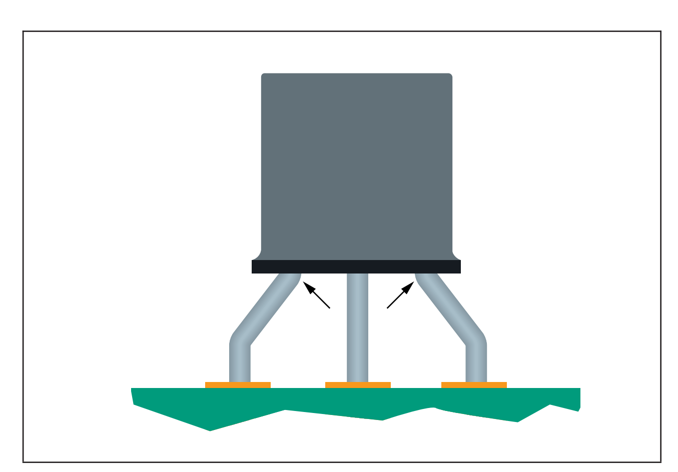


Figure 7-14

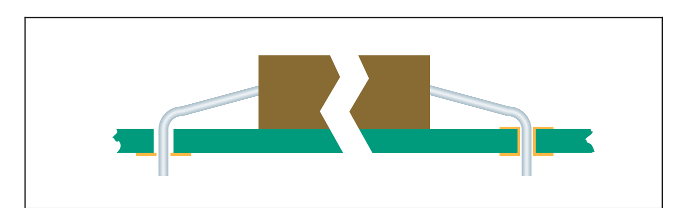
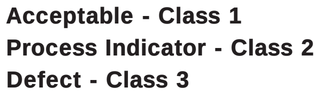


Figure 7-15



Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Lead bends less than one lead diameter away from body seal.

Defect - Class 1,2,3

- Damage or fracture of component body-to-lead seal.
- No stress relief.

7.1.2.3 Component Mounting – Lead Forming – Damage

These criteria are applicable whether leads are formed manually or by machine or die.



Figure 7-16

Acceptable - Class 1,2,3

- Component leads do not have nicks or deformation exceeding 10% of the diameter, width or thickness of the lead. See 5.2.1 for exposed basis metal criteria.

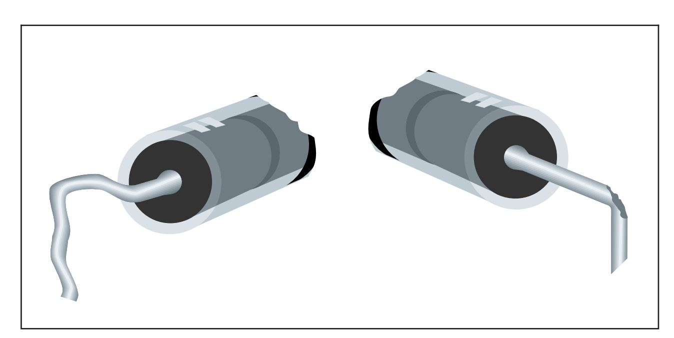




Figure 7-17

Defect - Class 1,2,3

- Lead is damaged more than 10% of the lead diameter.
- Lead deformed from repeated or careless bending.

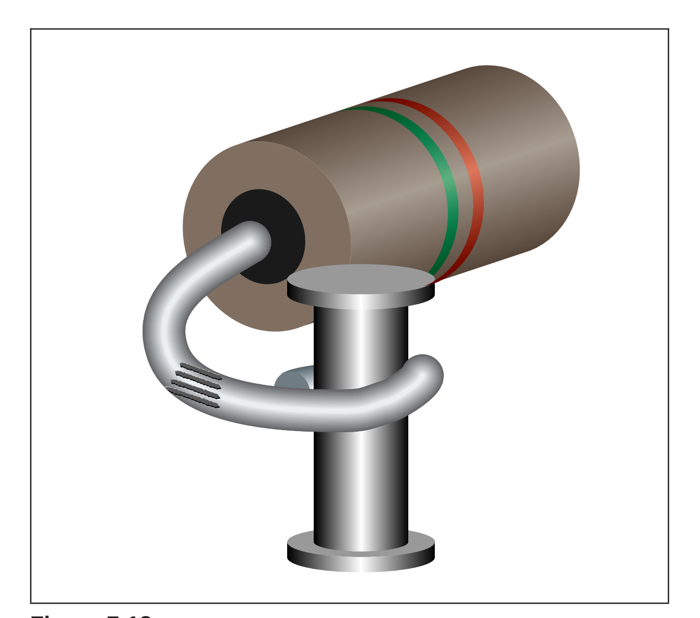


Figure 7-18

Defect - Class 1,2,3

- Heavy indentations such as serrated pliers mark.
- Lead diameter is reduced more than 10%.

7.1.3 Component Mounting – Leads Crossing Conductors

Sleeving must be used when called for by specification or drawing.

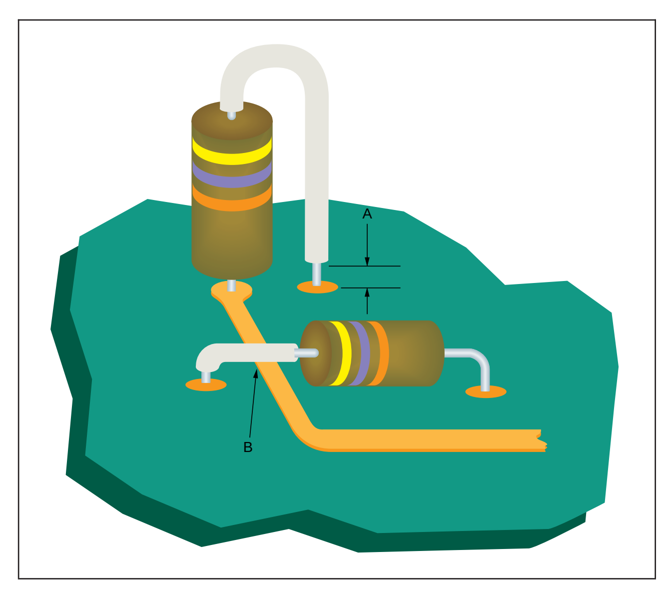


Figure 7-19

Acceptable - Class 1,2,3

- Sleeve does not interfere with formation of the required solder connection (A).
- Sleeve covers area of protection designated (B).

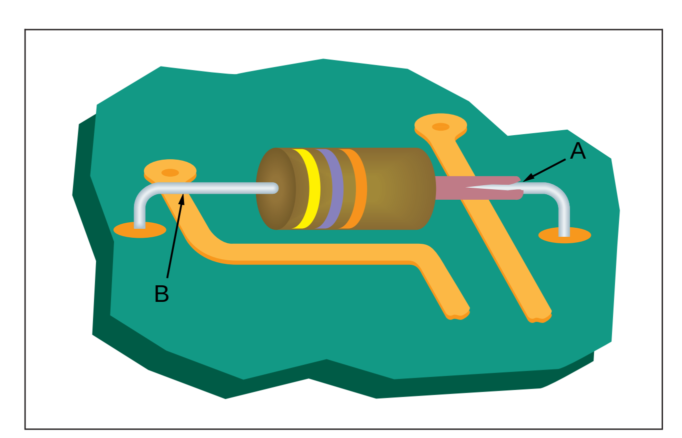


Figure 7-20

Acceptable - Class 1

- Unsleeved component lead crossing an electrically noncommon conductor that does not violate electrical spacing (B).

Defect - Class 2,3

- Splitting and/or unraveling of sleeving (A).
- A component lead crossing an electrically noncommon conductor with a clearance of less than 0.5 mm [0.020 in] with no separating insulator (lead sleeving or surface coating) (B).

Defect - Class 1,2,3

- Component leads and wires specified to have sleeving are not sleeved.
- Damaged/insufficient sleeving no longer provides protection from shorting.
- Sleeving interferes with formation of the required solder connection.

7.1.4 Component Mounting – Hole Obstruction

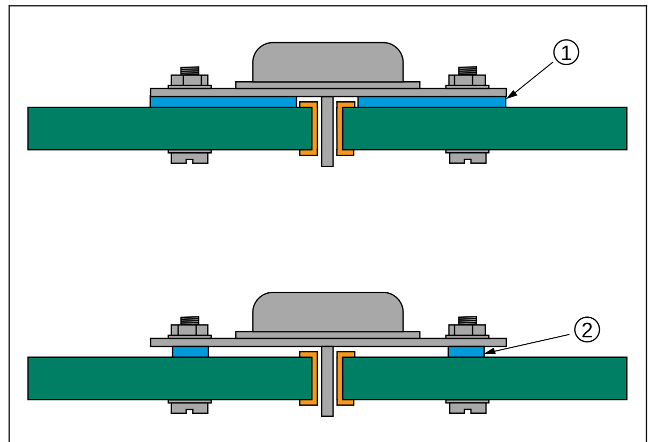


Figure 7-21
1. Insulating washer
2. Spacer

Acceptable - Class 1,2,3

- Parts and components are mounted such that they do not obstruct solder flow onto the primary side (solder destination side) lands of plated-through holes required to be soldered.

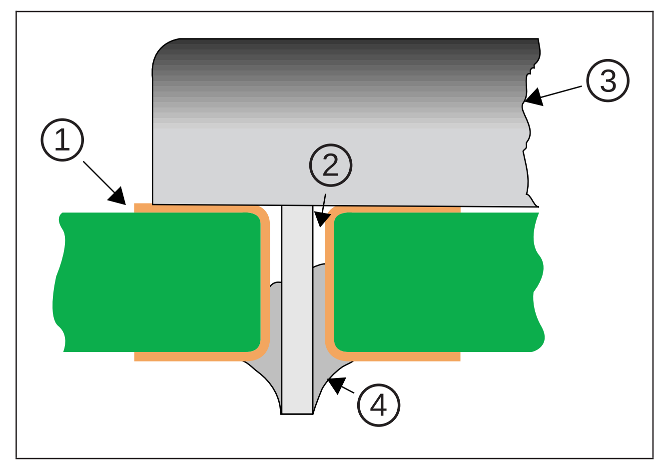


Figure 7-22
1. Hard mount
2. Air
3. Component body
4. Solder

Process Indicator - Class 2
Defect - Class 3

- Parts and components obstruct solder flow onto the primary side (solder destination side) lands of plated-through holes required to be soldered.

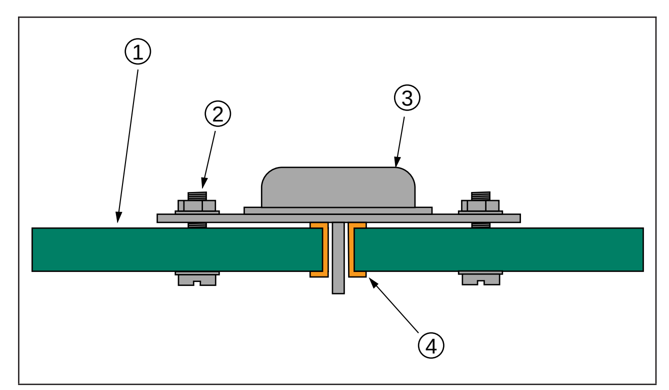


Figure 7-23
1. Nonmetal
2. Mounting hardware
3. Component case
4. Conductive pattern

Defect Class 1,2,3

- Parts and components are mounted such that they violate minimum electrical clearance.

7.1.5 Component Mounting – DIP/SIP Devices and Sockets

These criteria are applicable to Dual-in-Line Packages (DIP), Single-in-Line Packages (SIP) and sockets.

Note: In some cases a heat sink may be located between the component and the printed board; in these cases other criteria may be specified.

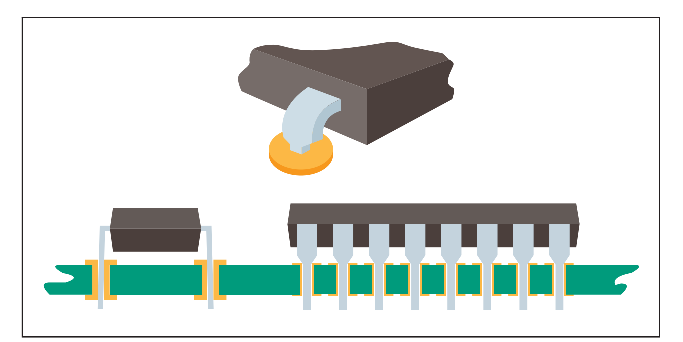


Figure 7-24

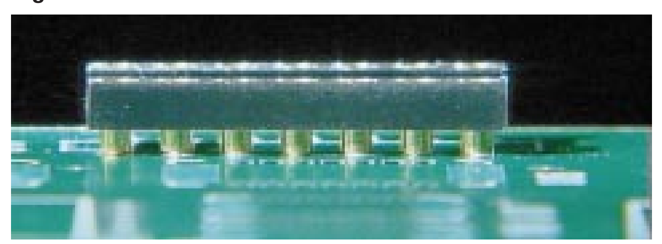


Figure 7-25

Target - Class 1,2,3

- Standoff step on all leads rests on the land.
- Lead protrusion meets requirements, see 7.4.3 and 7.5.3.

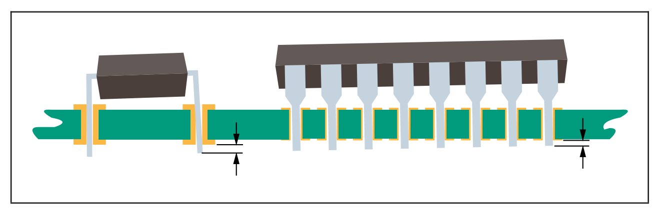


Figure 7-26

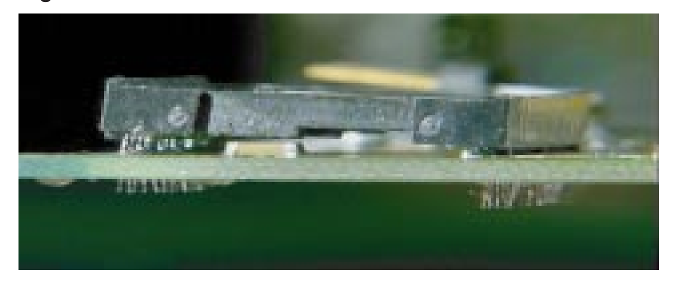


Figure 7-27

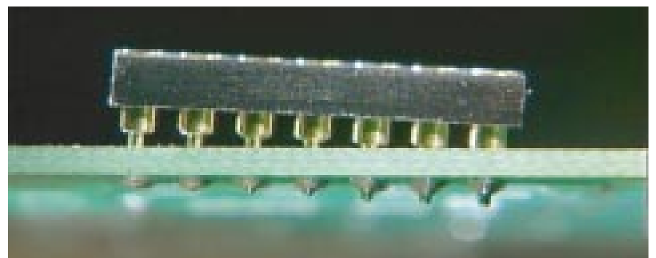


Figure 7-28

Acceptable - Class 1,2,3

- Amount of tilt is limited by minimum lead protrusion and height requirements.

7.1.5 Component Mounting – DIP/SIP Devices and Sockets (cont.)

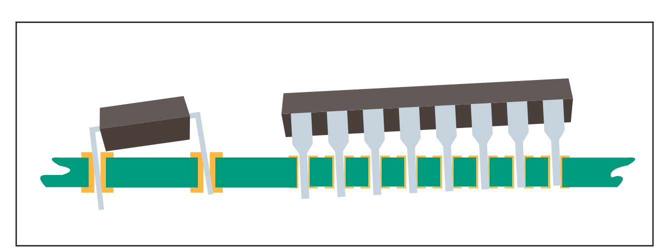


Figure 7-29

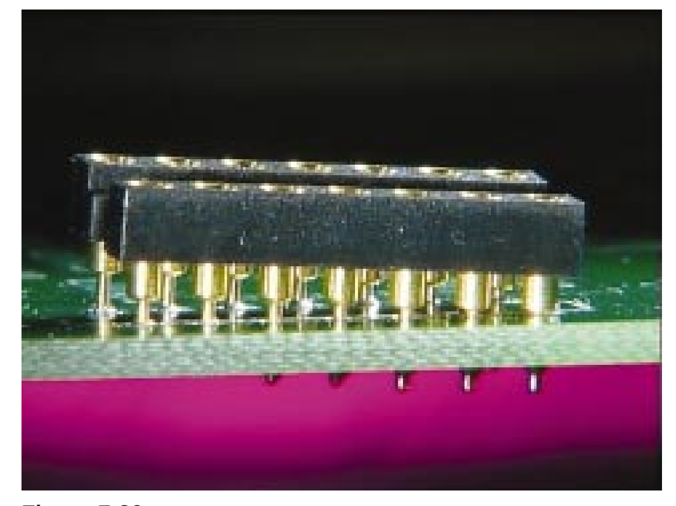


Figure 7-30

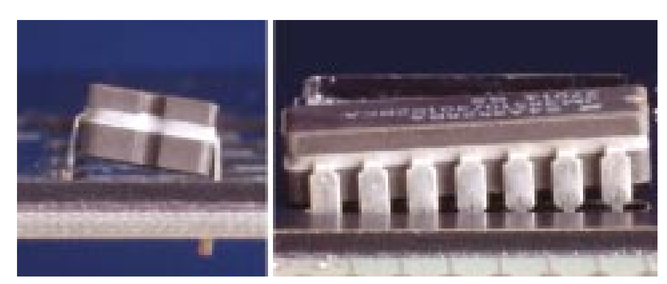


Figure 7-31

Defect - Class 1,2,3

- Tilt of the component exceeds maximum component height limits.
- Lead protrusion does not meet acceptance requirements due to tilt of component.

7.1.6 Component Mounting – Radial Leads – Vertical

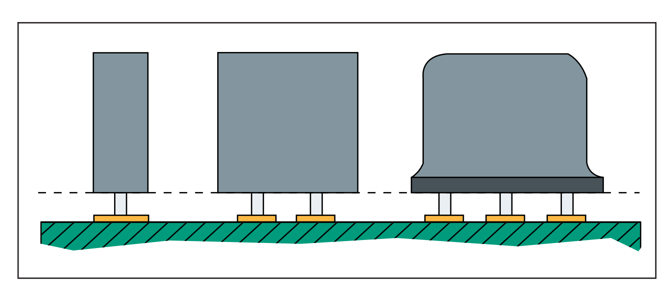


Figure 7-32

Target - Class 1,2,3

- Component is perpendicular and base is parallel to board.
- Clearance between base of component and board surface/land is between 0.3 mm [0.012 in] and 2 mm [0.079 in].

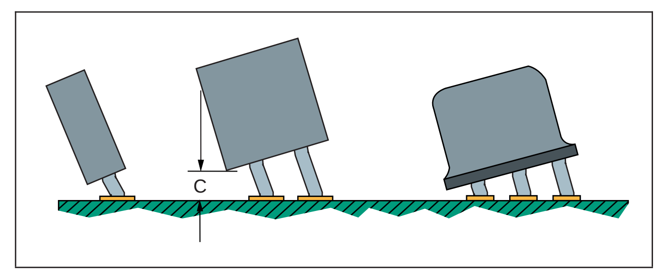


Figure 7-33

Acceptable - Class 1,2,3

- Component tilt does not violate minimum electrical clearance.

Process Indicator - Class 2,3

- Space between component base and board surface/land is less than 0.3 mm [0.012 in] or more than 2 mm [0.079 in], see 7.1.4.

Defect - Class 1,2,3

- Violates minimum electrical clearance.

Note: Some components cannot be tilted due to mating requirements with enclosures or panels, for example toggle switches, potentiometers, LCDs, and LEDs.

7.1.6.1 Component Mounting – Radial Leads – Vertical – Spacers

Spacers used for mechanical support or to compensate for component weight need to be in full contact with both component and board surface.

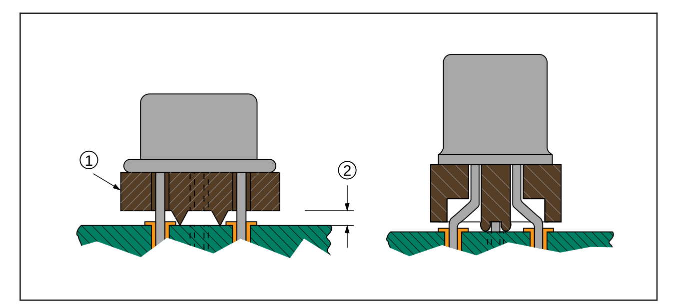


Figure 7-34
1. Spacer
2. Contact

Target - Class 1,2,3

- Spacer is in full contact with both component and board.
- Lead is properly formed.

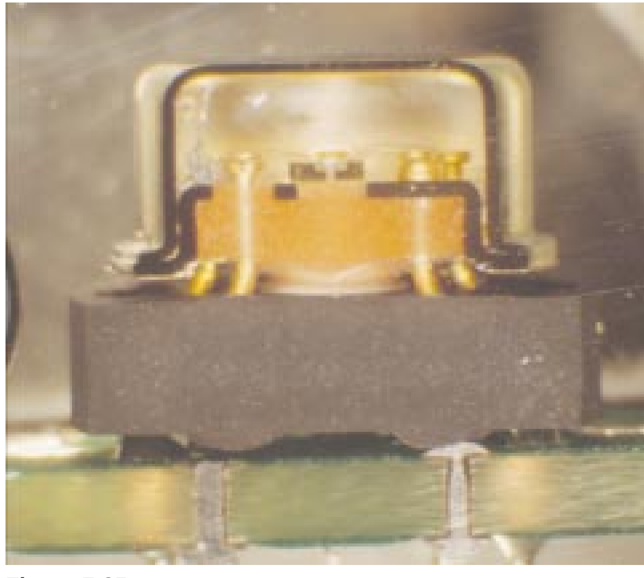


Figure 7-35

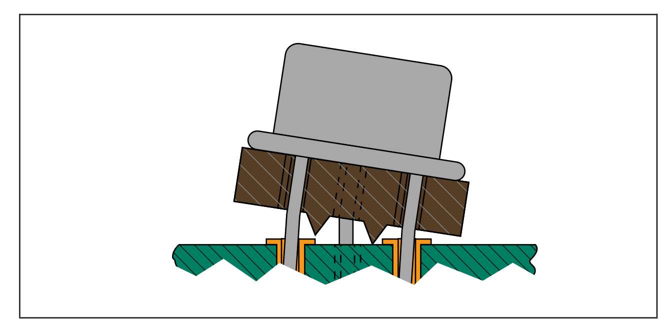


Figure 7-36

Acceptable (Supported Holes) - Class 1,2
Process Indicator (Supported Holes) - Class 3
Defect (Unsupported Holes) - Class 1,2,3

- Spacer is in partial contact with component and board.

7.1.6.1 Component Mounting – Radial Leads – Vertical – Spacers (cont.)

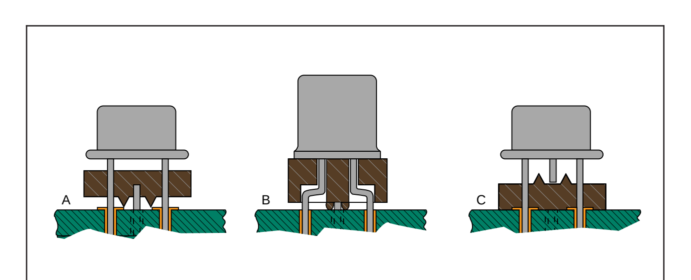


Figure 7-37

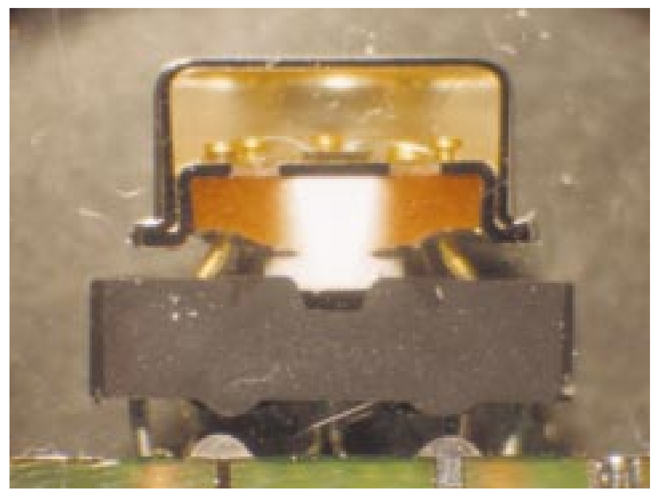


Figure 7-38

Acceptable (Supported Holes) - Class 1
Process Indicator (Supported Holes) - Class 2
Defect (Supported Holes) - Class 3

- Spacer is not in contact with component and board; Figure 7-37 (A), 7-38.
- Lead is improperly formed; Figure 7-37 (B).

Defect - Class 2,3

- Spacer is inverted; Figure 7-37 (C).
- Required spacer is missing.

7.1.7 Component Mounting – Radial Leads – Horizontal

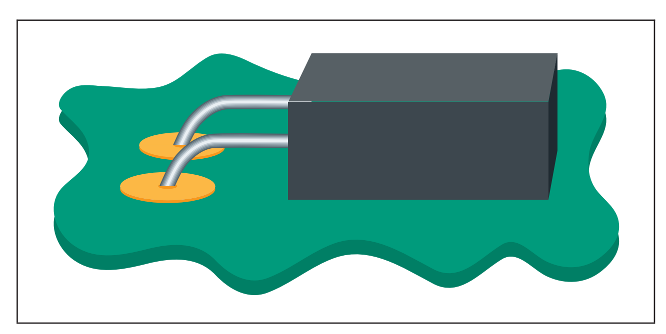


Figure 7-39

Target - Class 1,2,3

- The component body is in flat contact with the board's surface.
- Bonding material is present, if required. See 7.3.2.

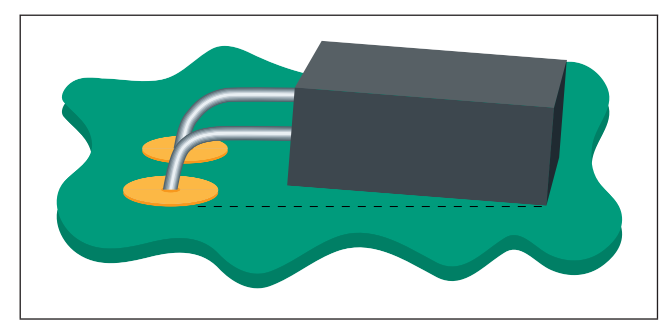


Figure 7-40

Acceptable - Class 1,2,3

- Component in contact with board on at least one side and/or surface.

Note: When documented on an approved assembly drawing, a component may be either side mounted or end mounted. The side or surface of the body, or at least one point of any irregularly configured component (such as certain pocketbook capacitors), needs to be in full contact with the printed board. The body may need to be bonded or otherwise secured to the board to prevent damage when vibration and shock forces are applied.

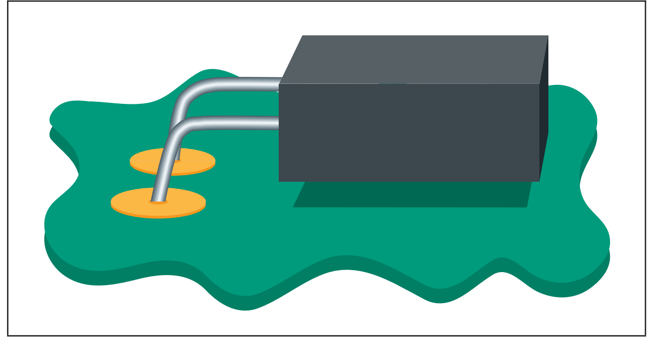


Figure 7-41

Defect - Class 1,2,3

- Unbonded component body not in contact with mounting surface.
- Bonding material not present if required.

7.1.8 Component Mounting – Connectors

These criteria apply to soldered connectors and unsoldered press fit connectors. For connector pin criteria see 4.3. For connector damage criteria see 9.5.

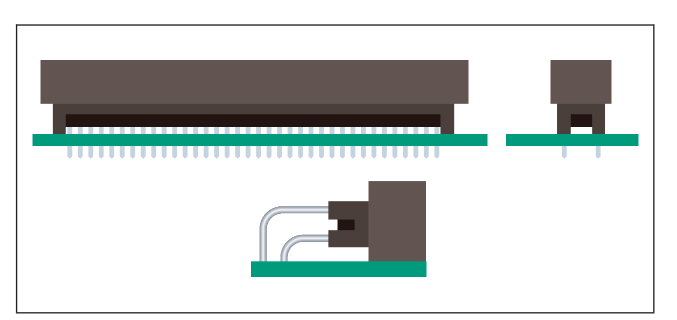


Figure 7-42

Target - Class 1,2,3

- Connector is flush with board.
- Lead protrusion meets requirements.
- Board lock (if equipped) is fully inserted/snapped into the board.

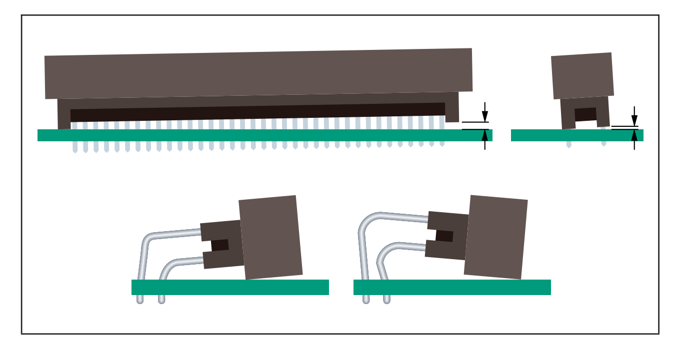


Figure 7-43

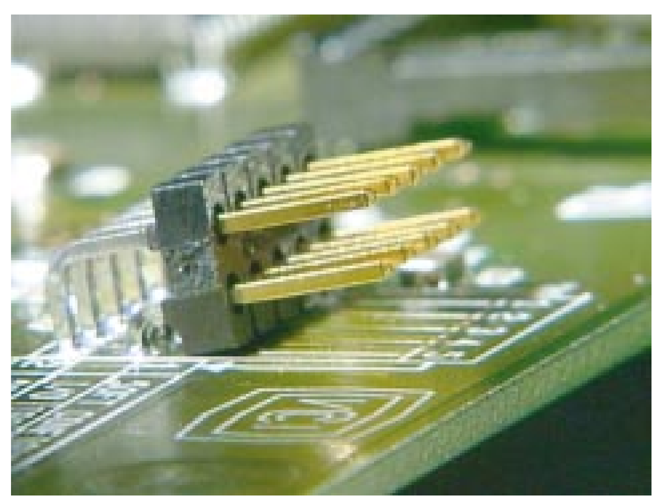


Figure 7-44

Acceptable - Class 1,2,3

- Back edge of connector is flush; entering edge of connector does not violate component height or lead protrusion requirements; see 7.4.3 or 7.5.3.
- Board lock is fully inserted/snapped through the board (non-floating housing.)
- Any tilt, provided:
  - Minimum lead protrusion is met.
  - Maximum height requirements are not exceeded.
  - Mates correctly.

7.1.8 Component Mounting – Connectors (cont.)

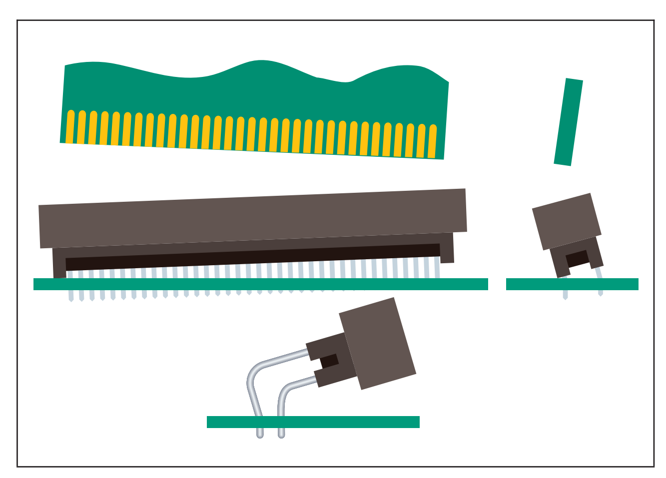


Figure 7-45

Defect - Class 1,2,3

- Will not mate when used in application due to angle.
- Component violates height requirements.
- Boardlock is not fully inserted/snapped into board.
- Lead protrusion does not meet acceptance requirements.

Note: Connectors need to meet form, fit and function requirements. A trial mating of connector to connector or to assembly may be required for final acceptance.

7.1.9 Component Mounting – High Power

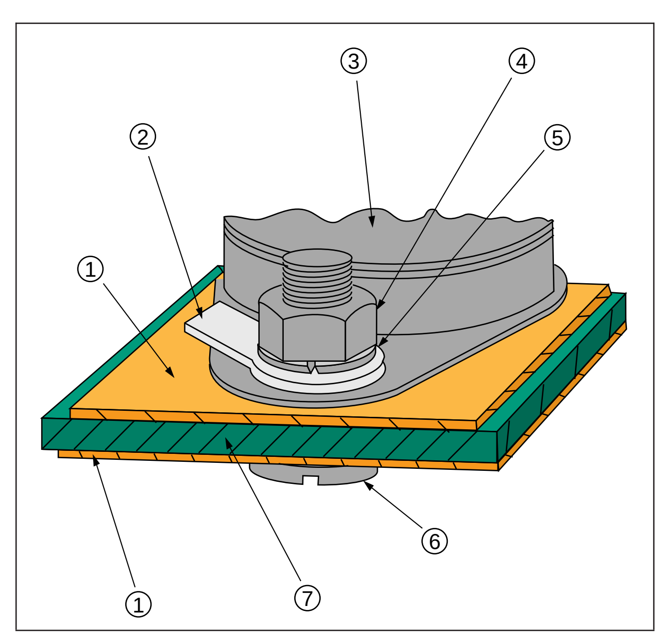


Figure 7-46
1. Metal
2. Terminal lug
3. Component case
4. Nut
5. Lock washer
6. Screw
7. Nonmetal

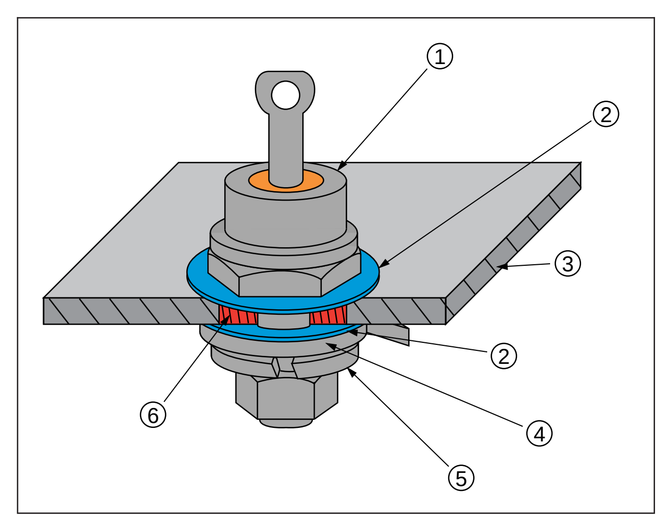


Figure 7-47
1. High power component
2. Insulating washer (when required)
3. Heat sink (may be metal or nonmetal)
4. Terminal lug
5. Lock washer
6. Insulator sleeve

Acceptable - Class 1,2,3

- Hardware in proper sequence.
- Leads on components attached by fastening devices are not clinched (not shown).
- Insulating washer provides electrical isolation when required.
- Thermal compound, if used, does not interfere with formation of required solder connections.

Note: Where a thermal conductor is specified, it must be placed between mating surfaces of the power device and the heat sink. Thermal conductors may consist of a thermally conductive washer or of an insulating washer with a thermally conductive compound.

7.1.9 Component Mounting – High Power (cont.)

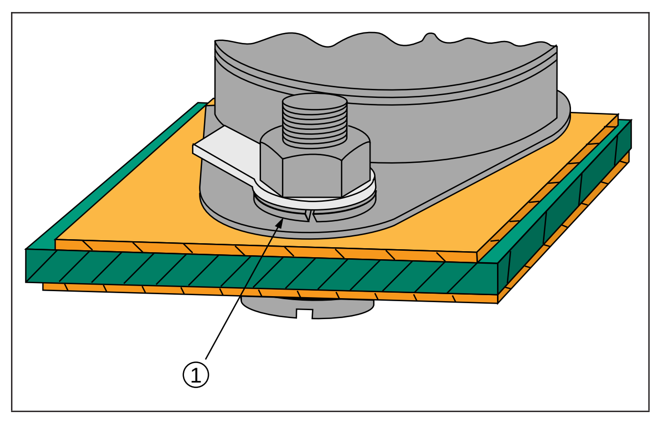


Figure 7-48

1. Lock washer between terminal lug and component case

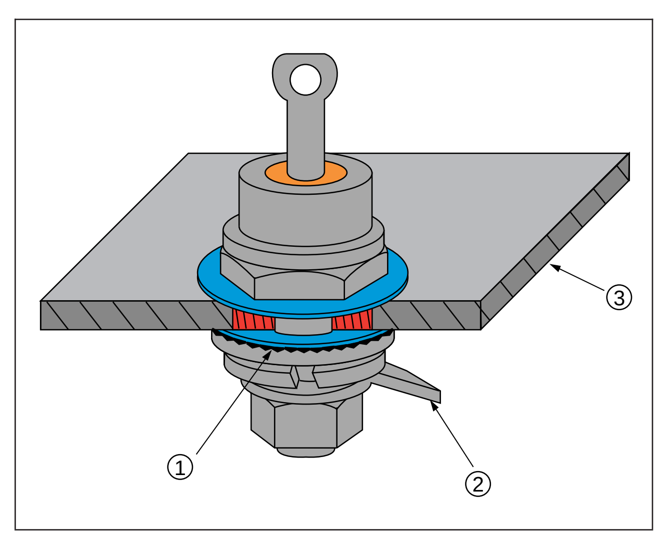


Figure 7-49

1. Sharp edge of washer against insulator
2. Terminal lug
3. Metal heat sink

Defect - Class 1,2,3

- Improper hardware sequence.
- Sharp edge of washer is against insulator.
- Hardware is not secure.
- Thermal compound, if used, does not permit formation of required solder connections.

7.2 Heatsinks

This section illustrates various types of heatsink mounting. Bonding with thermally conductive adhesives may be specified in place of hardware.

Visual inspection needs to include hardware security, component or hardware damage, and correct sequence of assembly.

The following additional issues need to be considered:

• The component has good contact with the heatsink.

• The hardware secures the component to the heatsink.

• The component and heatsink are flat and parallel to each other.

• The thermal compound/insulator (mica, silicone grease, plastic film, etc.) is applied properly.

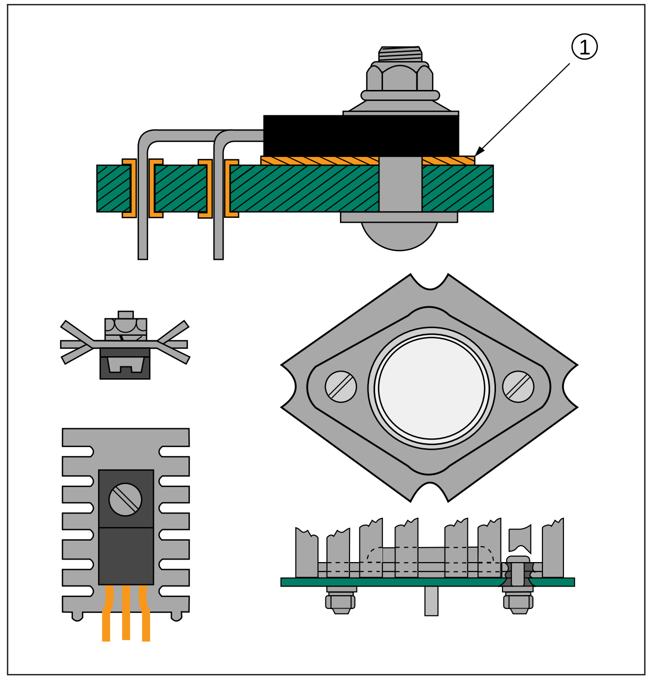


Figure 7-50
1. Heatsink

Acceptable - Class 1,2,3

• Heatsinks are mounted flush.

• No damage or stress on components.

7.2 Heatsinks (cont.)

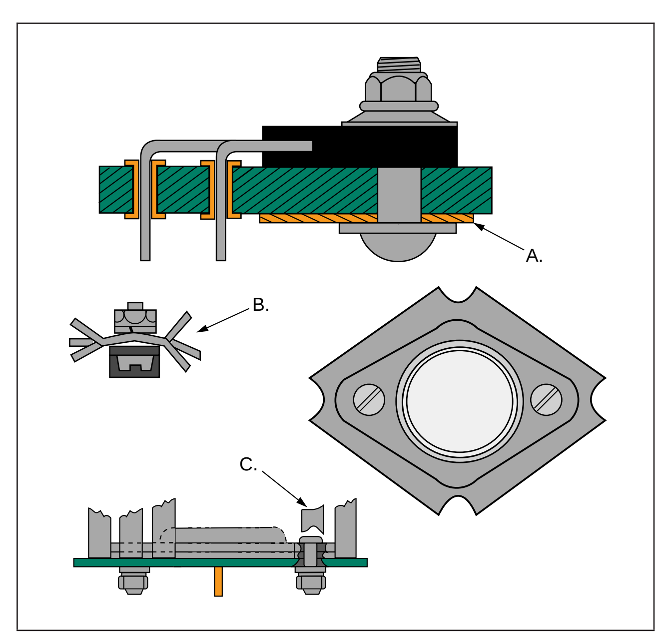


Figure 7-51

Defect - Class 1,2,3

- Heatsink on wrong side of board (A).
- Bent heatsink (B).
- Missing fins on heatsink (C).
- Heatsink not flush to board.
- Damage or stress to component.

7.2.1 Heatsinks – Insulators and Thermal Compounds

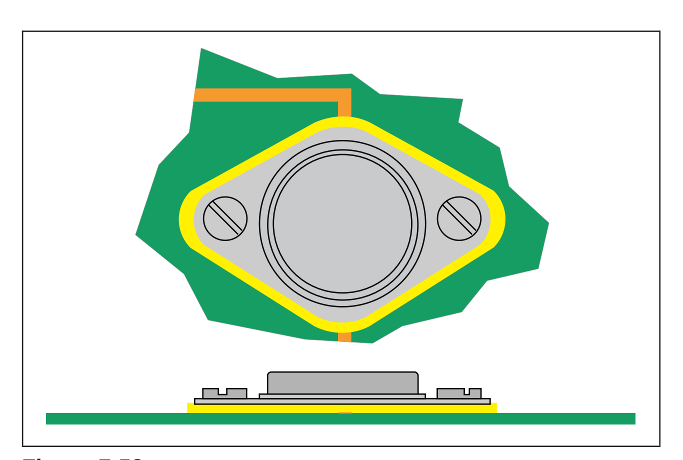


Figure 7-52

Target - Class 1,2,3

- Uniform border of mica, plastic film or thermal compound showing around edges of component.

Acceptable - Class 1,2,3

- Not uniform but evidence of mica, plastic film or thermal compound showing around edges of component.

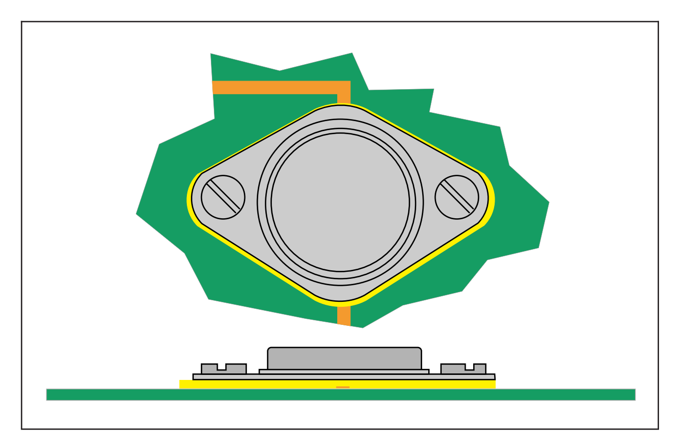


Figure 7-53

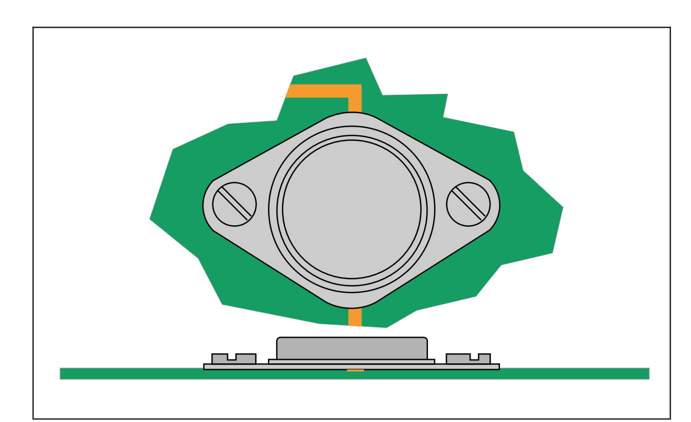


Figure 7-54

Defect - Class 1,2,3

- No evidence of insulating materials, or thermal compound (if required).
- Thermal compound precludes formation of required solder connection.

7.2.2 Heatsink – Contact

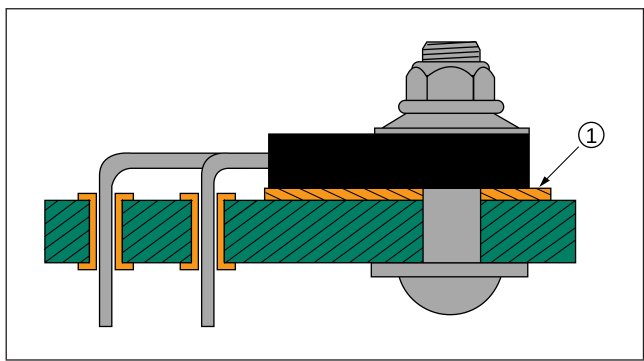


Figure 7-55
1. Heat sink

Target - Class 1,2,3

- Component and heatsink are in full contact with the mounting surface.
- Hardware meets specified attachment requirements.

Figure 7-56
1. Gap
2. Heat sink

Acceptable - Class 1,2,3

- Component not flush.
- Minimum 75% contact with mounting surface.
- Hardware meets mounting torque requirements if specified.

Figure 7-57
1. Heat sink
2. Gap

Defect - Class 1,2,3

- Component is not in contact with mounting surface.
- Hardware is loose.

7.3 Component Securing

7.3.1 Component Securing – Mounting Clips

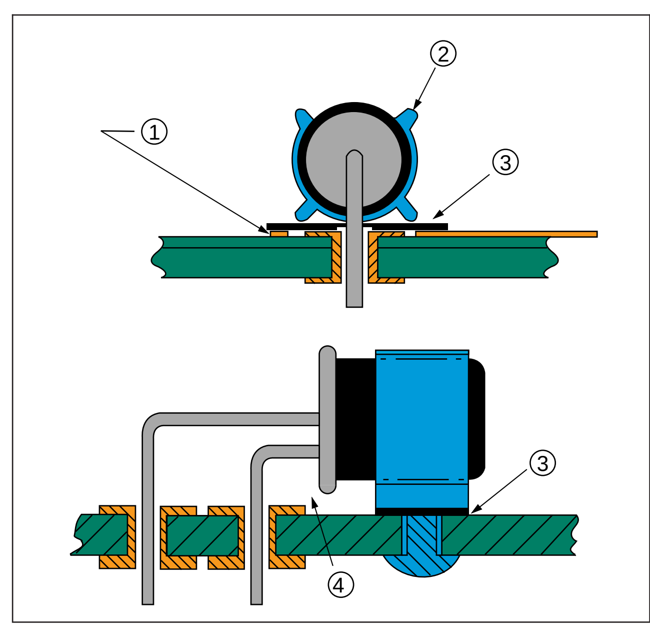


Figure 7-58

1. Conductive patterns
2. Metallic mounting clip
3. Insulation material
4. Clearance

Target - Class 1,2,3

- Uninsulated metallic component insulated from underlying circuitry with insulating material.
- Uninsulated metallic clips and holding devices used to secure components insulated from underlying circuitry with suitable insulating material.
- Spacing between land and uninsulated component body exceeds minimum electrical clearance.

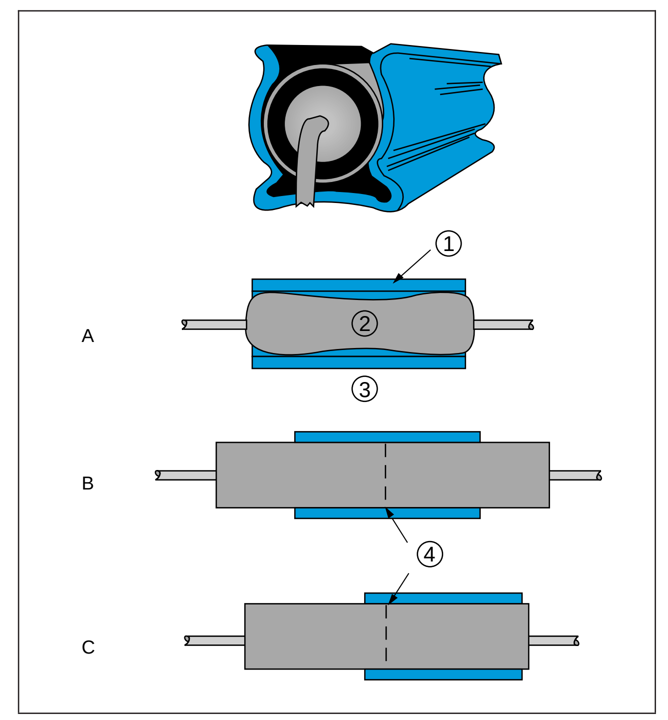


Figure 7-59

1. Clip
2. Nonsymmetrical body
3. Top view
4. Center of gravity

Acceptable - Class 1,2,3

- The clip makes contact to both sides of the component (A).
- The component is mounted with the center of gravity within the confines of the clip (B,C).
- The end of the component is flush with or extends beyond the end of the clip (C).

7.3.1 Component Securing – Mounting Clips (cont.)

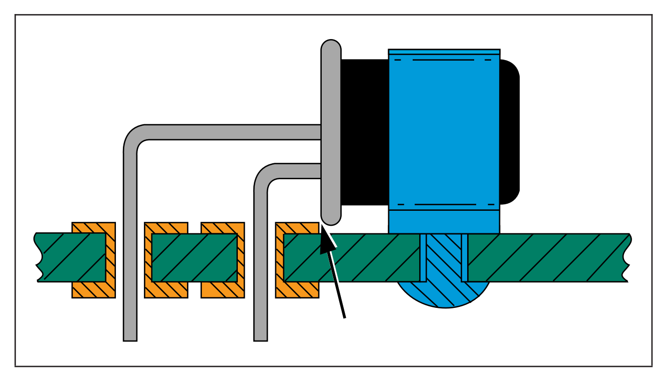


Figure 7-60

Defect - Class 1,2,3

- Spacing between land and uninsulated component body is less than minimum electrical clearance.

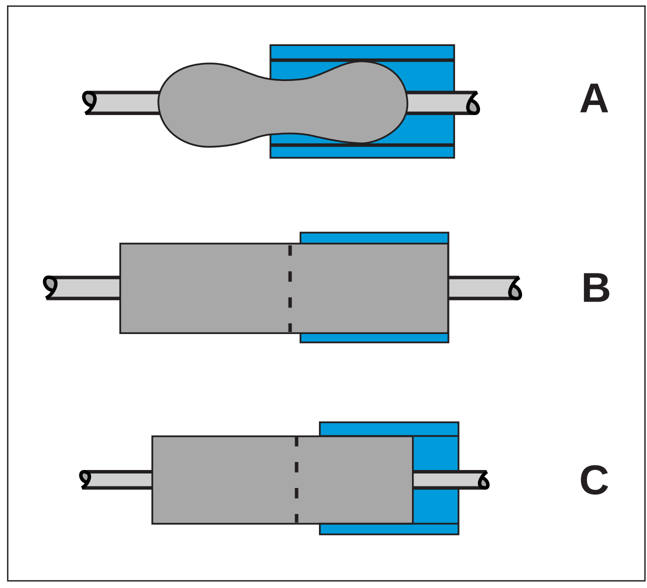


Figure 7-61

Defect - Class 1,2,3

- Clip does not restrain component (A).
- Component center or center of gravity not within the confines of the clip (B, C).

7.3.2 Component Securing – Adhesive Bonding – Nonelevated Components

These criteria do not apply to SMT components.

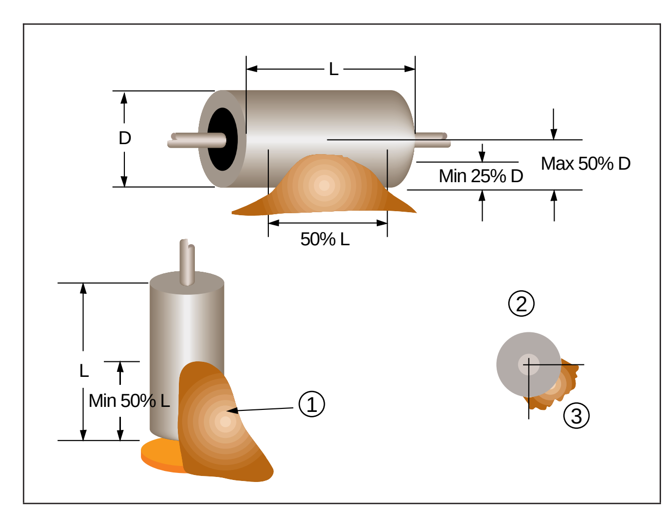


Figure 7-62
1. **Adhesive**
2. **Top view**
3. **25% Circumference**

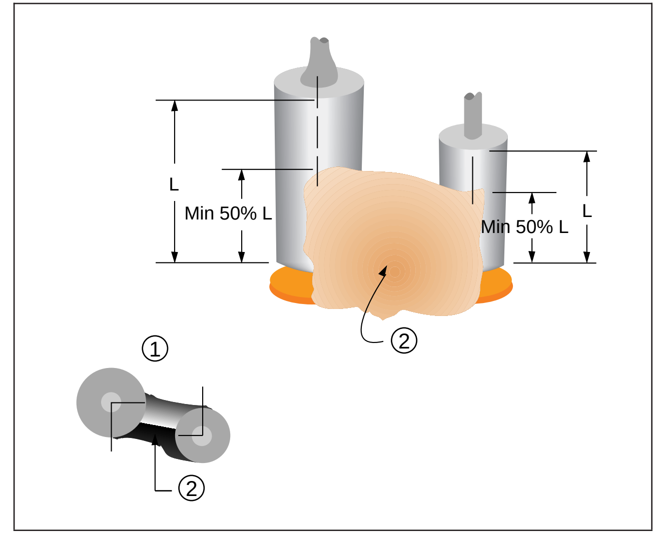


Figure 7-63
1. **Top view**
2. **Adhesive**

Acceptable - Class 1,2,3

- On a horizontally mounted component the adhesive adheres to component for at least 50% of its length (L), and 25% of its diameter (D), on one side. The build up of adhesive does not exceed 50% of the component diameter. Adhesion to the mounting surface is evident. The adhesive is approximately centered on the body.
- On a vertically mounted component the adhesive adheres to the component for at least 50% of its length (L), and 25% of its circumference. Adhesion to the mounting surface is evident.
- On multiple vertically mounted components the adhesive adheres to each component for at least 50% of its length (L), and the adhesion is continuous between components. Adhesion to the mounting surface is evident. The adhesive also adheres to each component for a minimum 25% of its circumference.
- Glass bodied components are sleeved, when required, prior to adhesive attachment.
- Adhesives, e.g., staking, bonding, do not contact an unsleeved area of a sleeved glass body component.

7.3.2 Component Securing – Adhesive Bonding – Nonelevated Components (cont.)

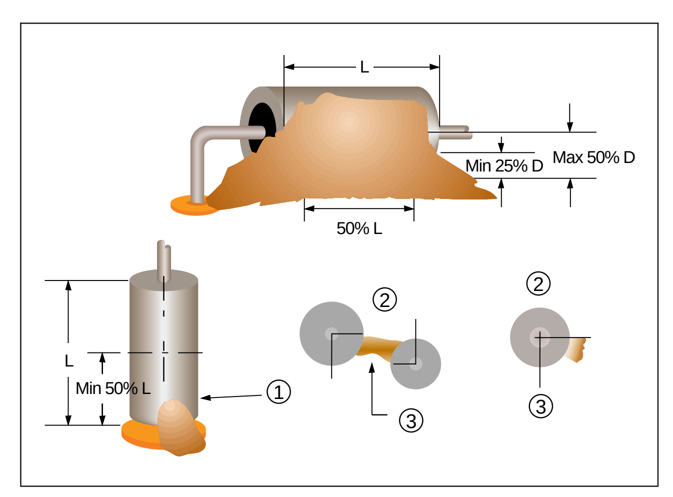


Figure 7-64
1. <50% length (L)
2. Top view
3. <25% circumference

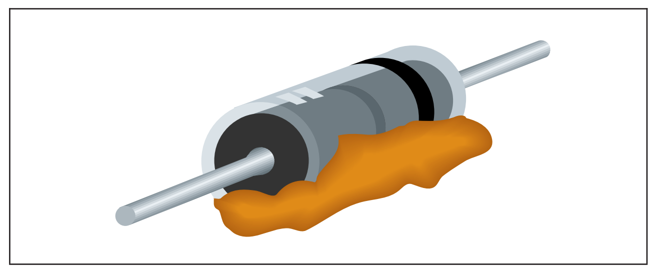


Figure 7-65

Acceptable - Class 1
Process Indicator - Class 2,3

- Adhesive in excess of 50% diameter of horizontally mounted components.

Defect - Class 1,2,3

- On a horizontally mounted component the adhesive adheres to component less than 50% of its length (L) or less than 25% of its diameter (D), on one side.
- On a vertically mounted component the adhesive adheres to the component less than 50% of its length (L) or less than 25% of its circumference.
- Adhesion to the mounting surface is not evident.
- Uninsulated metallic case components bonded over conductive patterns.
- Adhesive on areas to be soldered preventing compliance to Tables 7-3, 7-6 or 7-7.
- Adhesives, e.g., staking, bonding, contact an unsleeved area of a sleeved glass body component, Figure 7-65.

7.3.3 Component Securing – Adhesive Bonding – Elevated Components

This applies in particular to encapsulated or potted transformers and/or coils that are not mounted flush to the board.

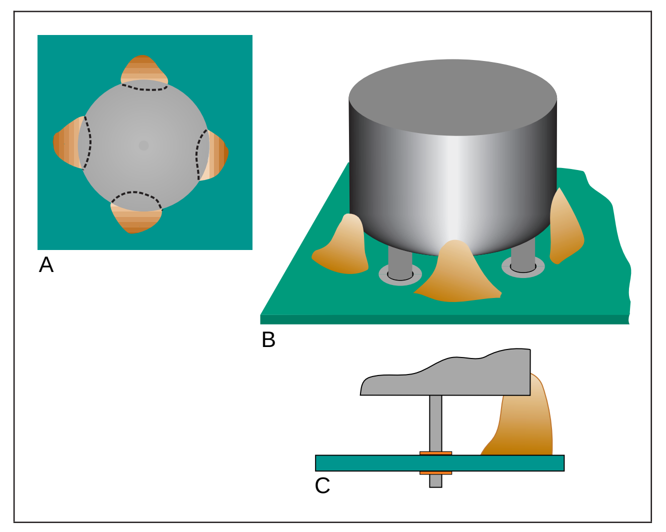


Figure 7-66

Acceptable - Class 1,2,3

- Bonding requirements should be specified in engineering documents, but as a minimum, components weighing 7g or more per lead are bonded to mounting surface in at least four places evenly spaced around component when no mechanical support is used (A).
- At least 20% of the total periphery of the component is bonded (B).
- Bonding material firmly adheres to both the bottom and sides of the component and to the printed wiring board (C).

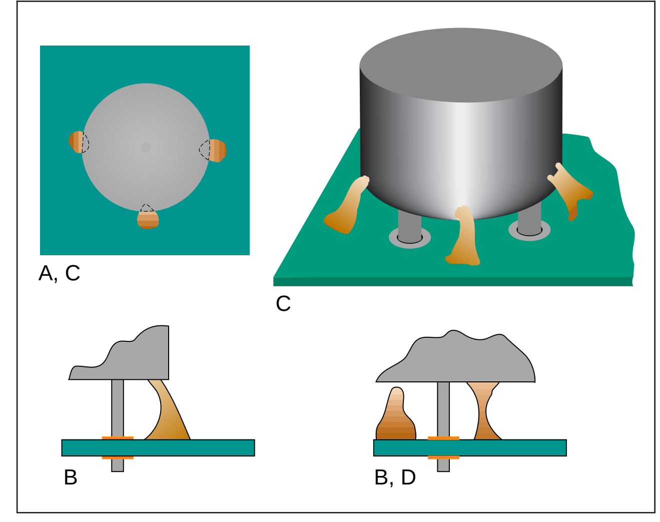


Figure 7-67

Defect - Class 1,2,3

- Bonding requirements are less than specified.
- Components weighing 7g or more per lead have less than four bonding spots (A).
- Any bonding spots failing to wet and show evidence of adhesion to both the bottom and side of the component and the mounting surface (B).
- Less than 20% of the total periphery of the component is bonded (C).
- The bonding material forms too thin a column to provide good support (D).

7.3.4 Component Securing – Wire Hold Down

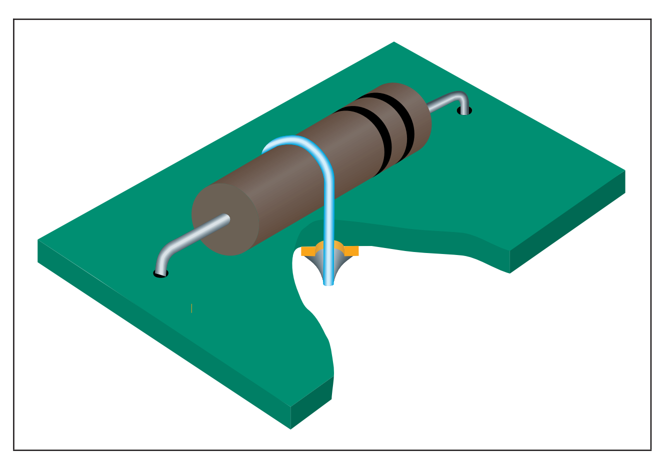


Figure 7-68

Acceptable - Class 1,2,3

- Component is held firmly against the mounting surface.
- There is no damage to the component body or insulation from the securing wire.
- Metal wire does not violate minimum electrical clearance.

7.4 Unsupported Holes

Component leads in through-hole connections may be terminated using a straight through, a partially clinched, or clinched configuration.

7.4.1 Unsupported Holes – Axial Leads – Horizontal

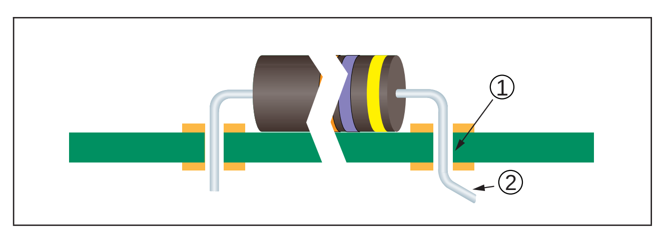


Figure 7-69
1. No plating in barrel
2. Clinch required for Class 3

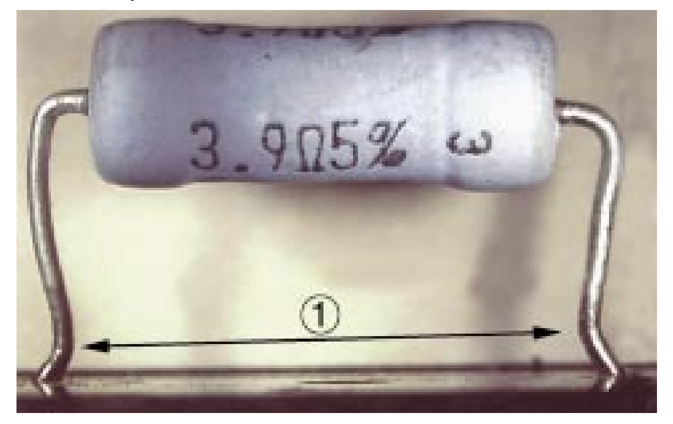


Figure 7-70
1. Lead form

Target - Class 1,2,3

- The entire body length of the component is in contact with the board surface.
- Components required to be mounted off the board are at minimum 1.5 mm [0.059 in] from the board surface; e.g., high heat dissipating.
- Components required to be mounted off the board are provided with lead forms at the board surface or other mechanical support to prevent lifting of solder land.

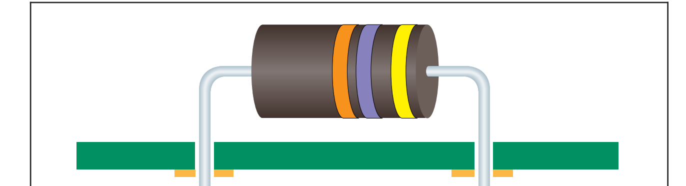


Figure 7-71

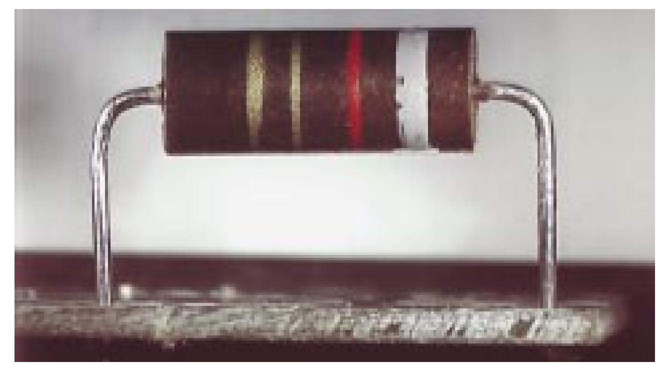


Figure 7-72

Defect - Class 1,2,3

- Components required to be mounted off the board are not provided with lead forms at the board surface or other mechanical support to prevent lifting of solder land.
- Components required to be mounted above the board surface are less than 1.5 mm [0.059 in].

Defect - Class 3

- No lead clinch.

7.4.2 Unsupported Holes – Axial Leads – Vertical

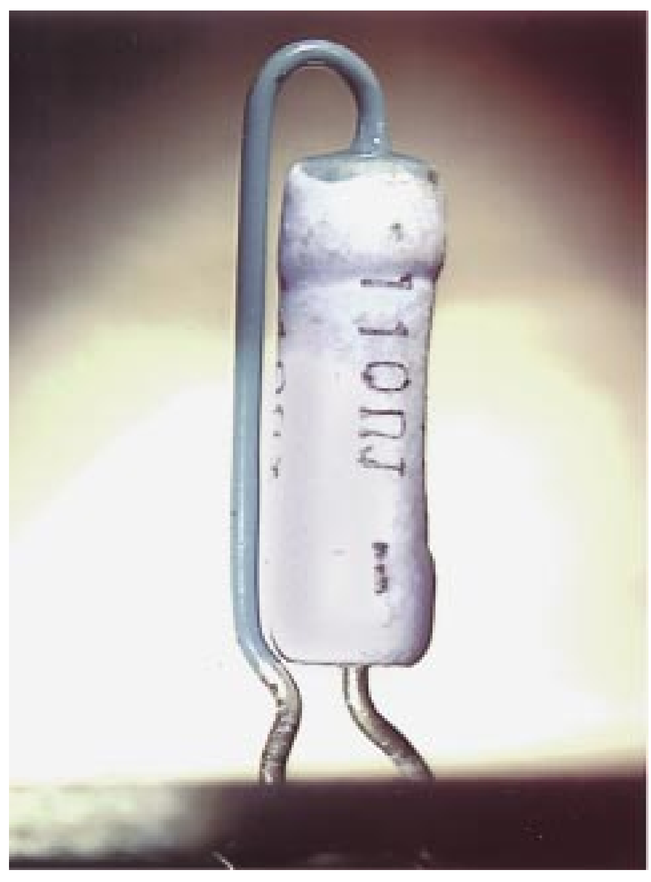


Figure 7-73

Target - Class 1,2,3

- Components that are mounted above the board surface in unsupported holes are provided with lead forms or other mechanical support to prevent lifting of solder land.

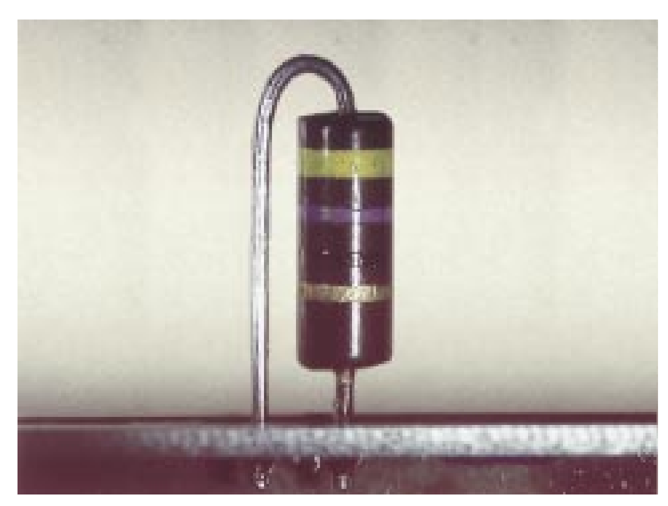


Figure 7-74

Defect - Class 1,2,3

- Components mounted above the board in unsupported holes are mounted without lead form at the board surface or other mechanical support.

7.4.3 Unsupported Holes – Wire/Lead Protrusion

Lead protrusion (Table 7-2) should not allow a possibility of violating of minimum electrical clearance, damage to soldered connections due to lead deflection, or penetration of static protective packaging during subsequent handling.

Note: High frequency applications may require more precise control of lead extensions to prevent violation of functional design considerations.

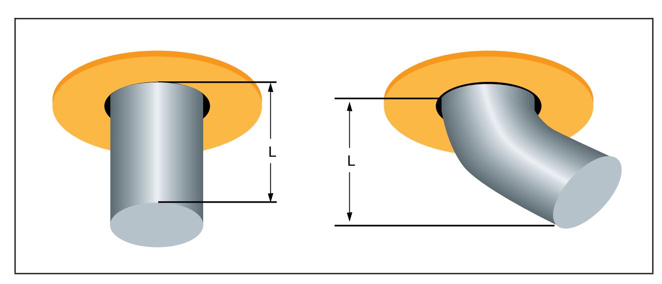


Figure 7-75

Target - Class 1,2,3

- The protrusion of leads and wires beyond the conductive surface is (L) or as specified on the specification or drawing.

Acceptable - Class 1,2,3

- The leads protrude beyond the land within the specified minimum and maximum (L) of Table 7-2, provided there is no danger of violating minimum electrical clearance.

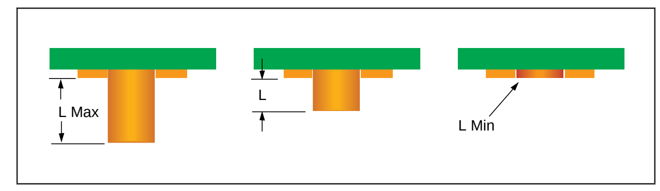


Figure 7-76

Defect - Class 1,2,3

- Lead protrusion does not meet Table 7-2 requirements.
- Lead protrusion violates minimum electrical clearance.
- Lead protrusion exceeds maximum design height requirements.

Table 7-2 Protrusion of Leads in Unsupported Holes

	Class 1	Class 2	Class 3
(L) min	End is discernible in solder		Sufficient to clinch
(L) max	No danger of shorts		

7.4.4 Unsupported Holes – Wire/Lead Clinches

This section applies to terminations with a clinching requirement. Other requirements may be specified on relevant specifications or drawings. Partially clinched leads for part retention are considered as unclinched leads and need to meet protrusion requirements.

Class 3 Lead terminations in unsupported holes are clinched a minimum of 45°.

The clinch should be sufficient to provide mechanical restraint during the soldering process. The orientation of the clinch relative to any conductor is optional. DIP leads should be bent outward from the longitudinal axis of the body. Tempered leads and leads greater than 1.3 mm [0.050 in] should not be bent nor formed for mounting purposes. Tempered leads are not terminated with a full-clinched configuration.

As a minimum, the lead is discernible in the completed solder connection. The lead meets the requirements of Table 7-2 when measured vertically from the land surface and does not violate minimum electrical clearance requirements.

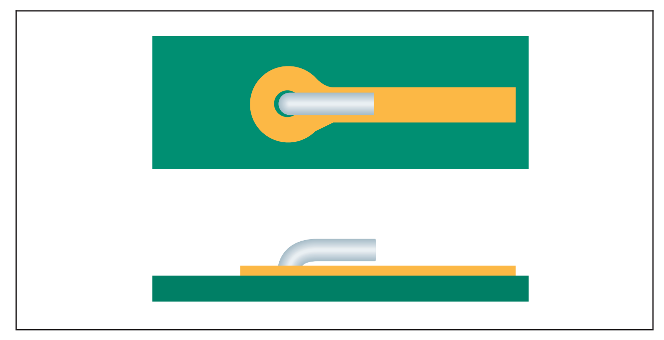


Figure 7-77

Target - Class 1,2,3

- Lead end is parallel to the board and direction of the clinch is along the connecting conductor.

7.4.4 Unsupported Holes – Wire/Lead Clinches (cont.)

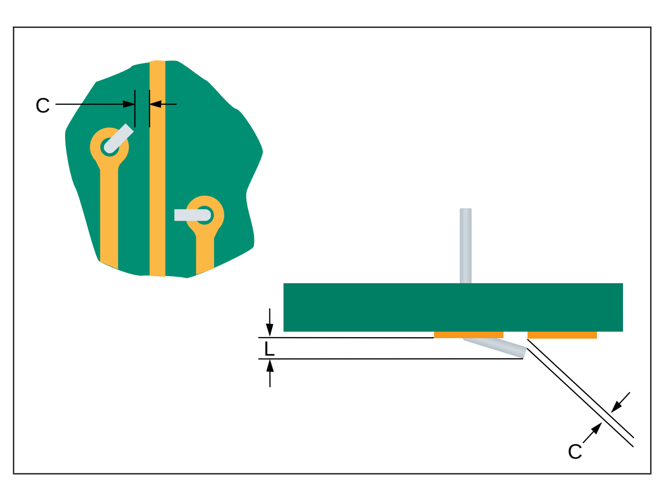


Figure 7-78

Acceptable - Class 1,2,3

- The clinched lead does not violate the minimum electrical clearance (C) between noncommon conductors.
- The protrusion (L) beyond the land is not greater than the similar length allowed for straight-through leads.
- The leads protrude beyond the land within the specified minimum and maximum (L) of Table 7-2, provided there is no violation of minimum electrical clearance.

Acceptable - Class 3

- Lead in unsupported hole is clinched a minimum of 45°.

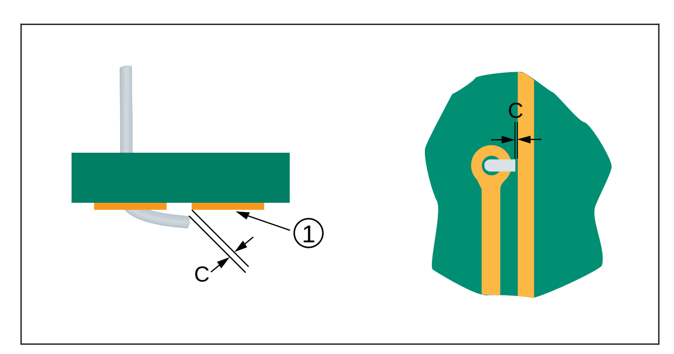


Figure 7-79
1. Noncommon conductor

Defect - Class 1,2,3

- The lead is clinched toward an electrically noncommon conductor and violates minimum electrical clearance (C).
- Lead protrusion is insufficient for clinch, if required.



Figure 7-80

Defect - Class 3

- Lead in unsupported hole is not clinched a minimum of 45° (not shown).

7.4.5 Unsupported Holes – Solder

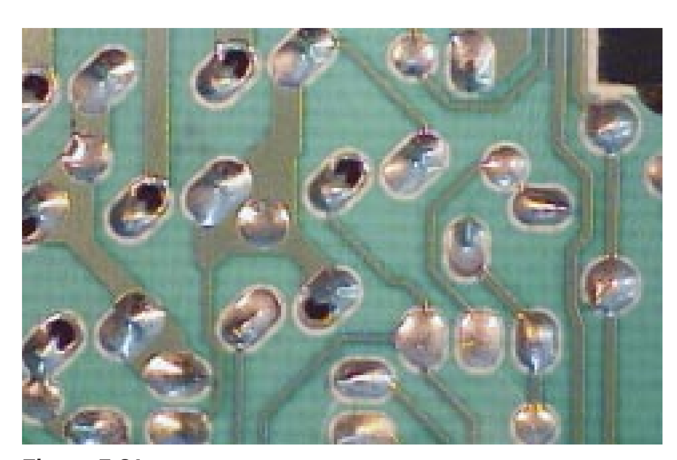


Figure 7-81

Table 7-3 Unsupported Holes with Component Leads, Minimum Acceptable Conditions[3]

Criteria	Class 1	Class 2	Class 3
A. Fillet and wetting of lead and land[1]	270°	270°	330°
B. Percentage of land area covered with wetted solder[2]	75%	75%	75%

Note 1. For Class 3, lead is wetted in the clinched area.
Note 2. Solder is not required to cap or cover the hole.
Note 3. Double sided boards with functional lands on both sides need to comply to A and B on both sides.

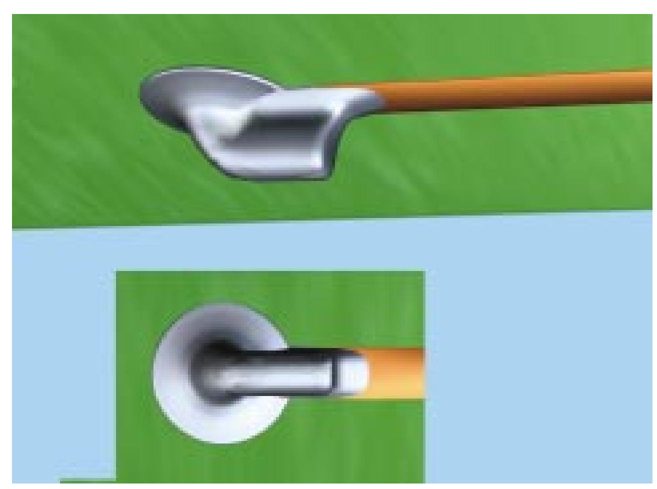


Figure 7-82

Target Class 1,2,3

- Solder termination, (land and lead), covered with wetted solder and outline of lead discernible in the solder fillet.
- No void areas or surface imperfections.
- Lead and land are well wetted.
- Lead is clinched.
- 100% solder fillet around lead.

7.4.5 Unsupported Holes – Solder (cont.)

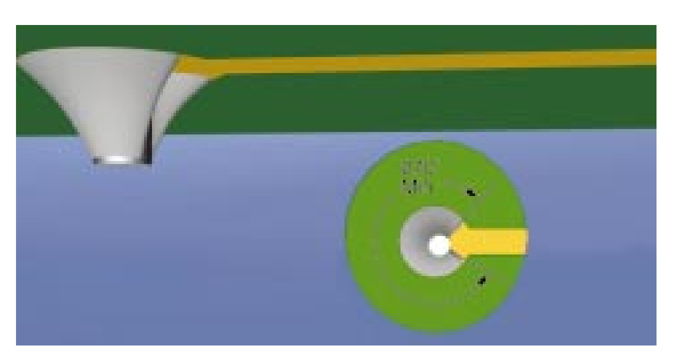


Figure 7-83

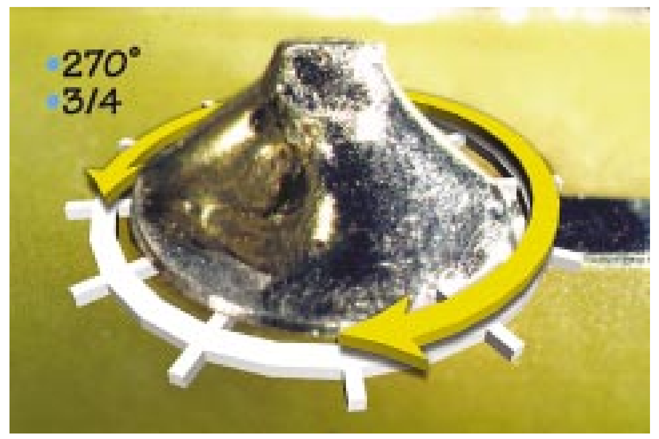


Figure 7-84

Acceptable - Class 1,2

- Solder coverage meets requirements of Table 7-3.



Figure 7-85



Figure 7-86

Acceptable - Class 3

- Lead is wetted in the clinched area.
- Minimum of 330° fillet and wetting.

7.4.5 Unsupported Holes – Solder (cont.)

Acceptable - Class 1,2,3

- Minimum 75% of land area covered with wetted solder on the secondary side (not shown).

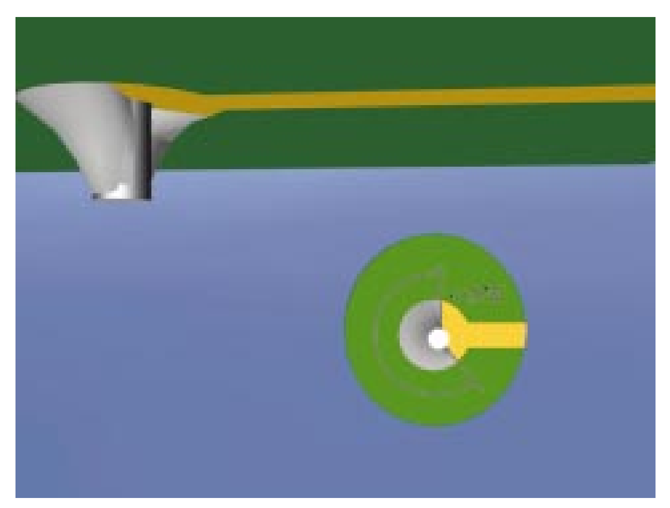


Figure 7-87

Defect - Class 1,2

- Solder connection of straight through termination does not meet minimum of 270° circumferential fillet or wetting.
- Less than 75% land coverage.

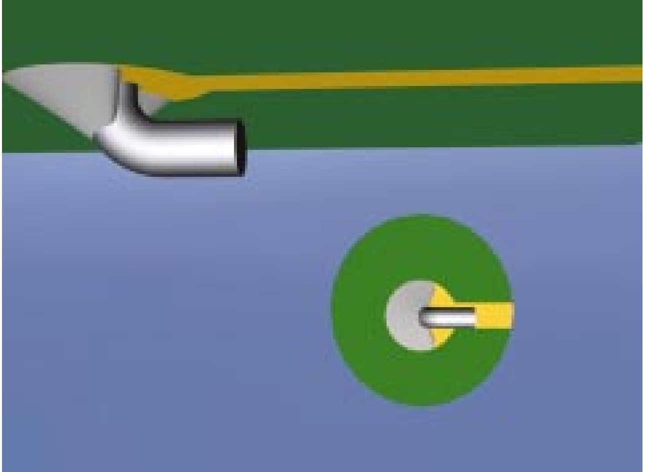


Figure 7-88

Defect - Class 3

- Solder connection does not meet 330° circumferential fillet or wetting.
- Lead not clinched (not shown).
- Lead not wetted in clinched area.
- Less than 75% land coverage.



Figure 7-89

Defect - Class 1,2,3

- Lead not discernible due to excess solder.

7.4.6 Lead Cutting after Soldering

The criteria in 7.5.5.8 are also applicable to solder connections in unsupported holes.

7.5 Supported Holes

7.5.1 Supported Holes – Axial Leaded – Horizontal

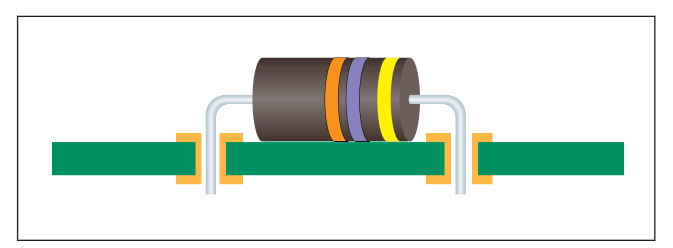


Figure 7-90

Target - Class 1,2,3

- The entire body length of the component is in contact with the board surface.
- Components required to be mounted off the board are at least 1.5 mm [0.059 in] from the board surface; e.g., high heat dissipating.

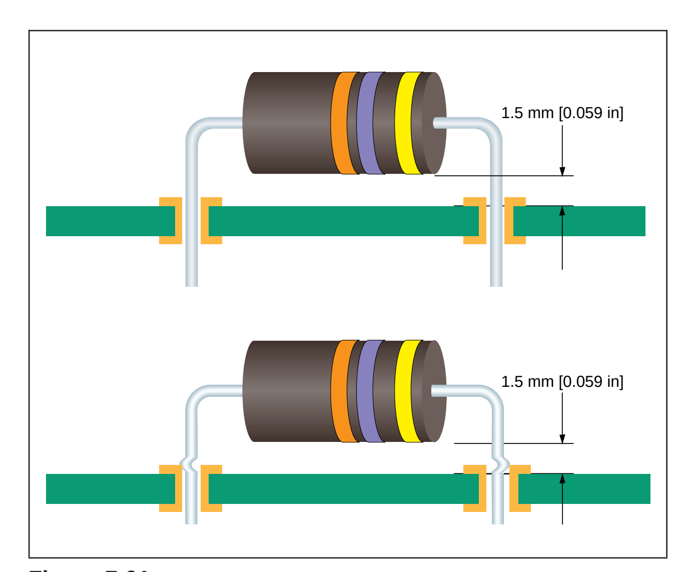


Figure 7-91

7.5.1 Supported Holes – Axial Leaded – Horizontal (cont.)

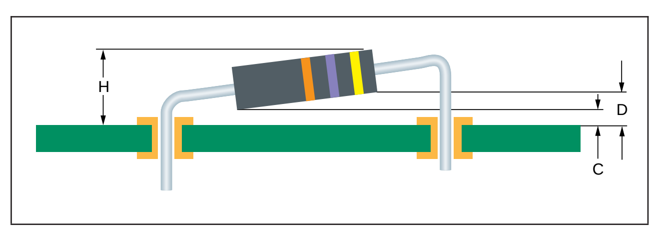


Figure 7-92

Acceptable - Class 1,2

- The maximum clearance (C) between the component and the board surface does not violate the requirements for lead protrusion (see 7.5.3) or component height (H). (H) is a user-determined dimension.

Acceptable - Class 3

- Clearance (C) between the component body and the board does not exceed 0.7 mm [0.028 in].

Process Indicator - Class 3

- The farthest distance between the component body and the board (D) is larger than 0.7 mm [0.028 in].

Defect - Class 3

- The distance between the component body and the board is larger than 1.5 mm [0.059 in].

Defect - Class 1,2,3

- Component height exceeds user-determined dimension (H).
- Components required to be mounted above the board surface are less than 1.5 mm [0.059 in] from the board surface.

7.5.2 Supported Holes – Axial Leaded – Vertical

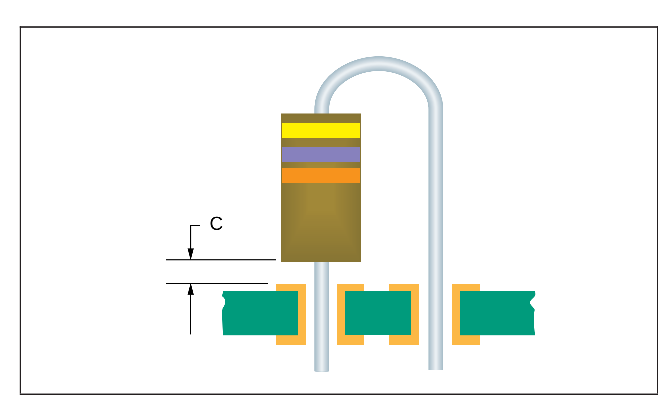


Figure 7-93

Target - Class 1,2,3

- The clearance (C) of the component body or weld bead above the land is 1 mm [0.039 in].
- The component body is perpendicular to the board.
- The overall height does not exceed the height specified.

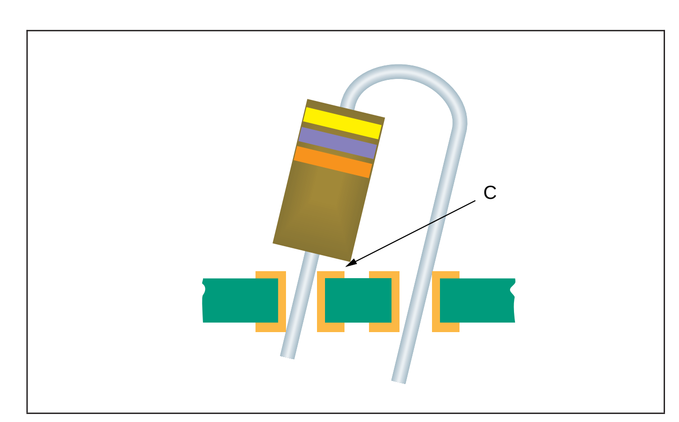


Figure 7-94

Acceptable - Class 1,2,3

- The component or weld bead clearance (C) above the land is not outside the range given in Table 7-4.
- The angle of the component lead does not cause a violation of minimum electrical clearance.

Table 7-4 Component to Land Clearance

	Class 1	Class 2	Class 3
C (min)	0.1 mm [0.0039 in]	0.4 mm [0.016 in]	0.8 mm (0.031 in)
C (max)	6 mm [0.24 in]	3 mm [0.12 in]	1.5 mm [0.059 in]

7.5.2 Supported Holes – Axial Leaded – Vertical (cont.)

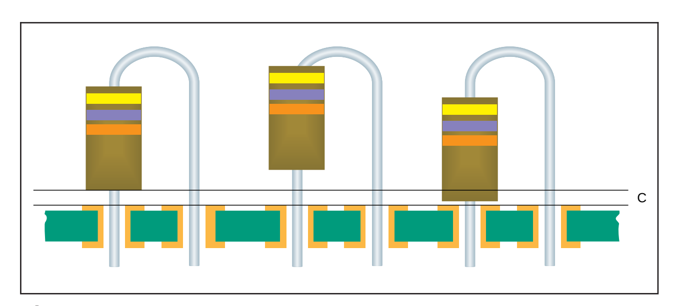


Figure 7-95

Acceptable - Class 1
Process Indicator - Class 2,3

- The component clearance (C) is greater than the maximum given in Table 7-4.
- The component or weld bead clearance (C) is less than the minimum given in Table 7-4.

Defect - Class 1,2,3

- Components violate minimum electrical clearance.
- Component height does not meet form, fit or function.
- Component height exceeds user-determined dimension (H).

7.5.3 Supported Holes – Wire/Lead Protrusion

Lead protrusion (Table 7-5) should not allow a possibility of violating minimum electrical spacing, damage to soldered connections due to lead deflection, or penetration of static protective packaging during subsequent handling.

Note: High frequency applications may require more precise control of lead extensions to prevent violation of functional design considerations.

Table 7-5 Protrusion of Leads in Supported Holes

	Class 1	Class 2	Class 3
(L) min.	End is discernible in the solder.[1]		
(L) max.	No danger of shorts	2.5 mm [0.0984 in]	1.5 mm [0.0591 in]

Note 1. For boards greater than 2.3 mm [0.0906 in] thick, components having pre-established lead lengths, e.g., DIPs, sockets, connectors, as a minimum components or lead shoulders need to be flush to the board surface, but lead end may not be visible in the subsequent solder connection, see 1.4.2.5.

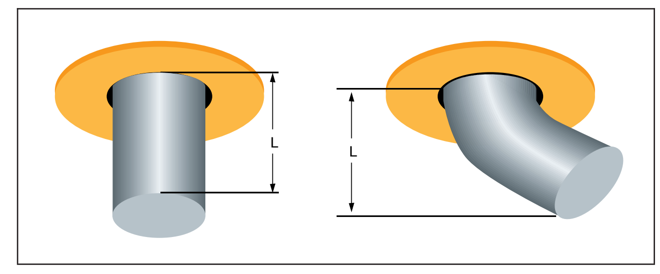


Figure 7-96

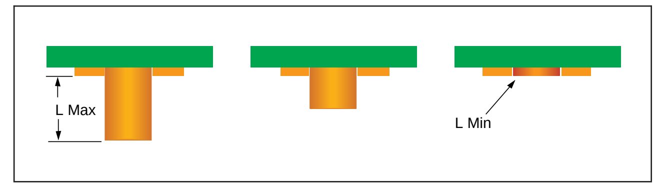


Figure 7-97

Acceptable - Class 1,2,3

- The leads protrude beyond the land within the specified minimum and maximum (L) of Table 7-5, provided there is no danger of violating minimum electrical clearance.

Defect - Class 1,2,3

- Lead protrusion does not meet the requirements of Table 7-5.
- Lead protrusion violates minimum electrical clearance.
- Lead protrusion exceeds maximum design height requirements.

7.5.4 Supported Holes – Wire/Lead Clinches

Component leads in through-hole connections may be terminated using a straight through, partially clinched or clinched configuration. The clinch should be sufficient to provide mechanical restraint during the soldering process. The orientation of the clinch relative to any conductor is optional. DIP leads should be bent outward from the longitudinal axis of the body. Tempered leads and leads greater than 1.3 mm [0.050 in] should not be bent nor formed for mounting purposes.

As a minimum, the lead is discernible in the completed solder connection. The lead meets the requirements of Table 7-5 when measured vertically from the land surface and does not violate minimum electrical clearance requirements.

This section applies to terminations with a clinching requirement. Other requirements may be specified on relevant specifications or drawings. Partially clinched leads for part retention are considered as unclinched leads and need to meet protrusion requirements.

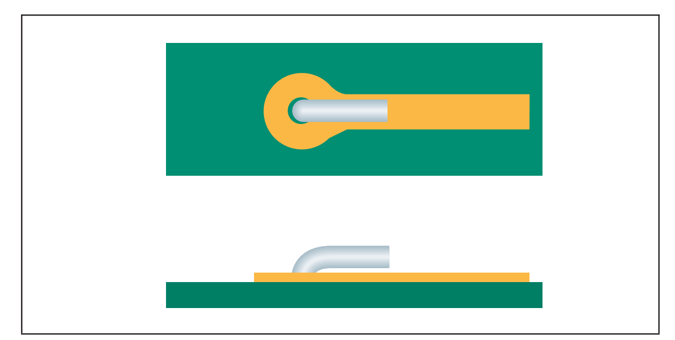


Figure 7-98

Target - Class 1,2,3

- Lead end is parallel to the board and direction of the clinch is along the connecting conductor.

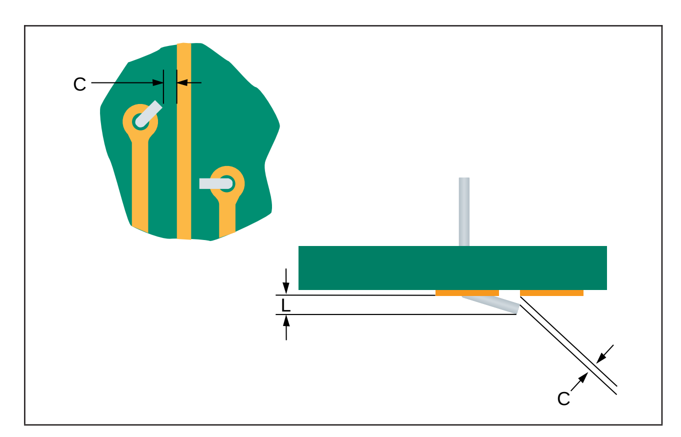


Figure 7-99

Acceptable - Class 1,2,3

- The clinched lead does not violate the minimum electrical clearance (C) between noncommon conductors.
- The protrusion (L) beyond the land is not greater than the similar length allowed for straight-through leads. See Figure 7-99 and Table 7-5.

7.5.4 Supported Holes – Wire/Lead Clinches (cont.)

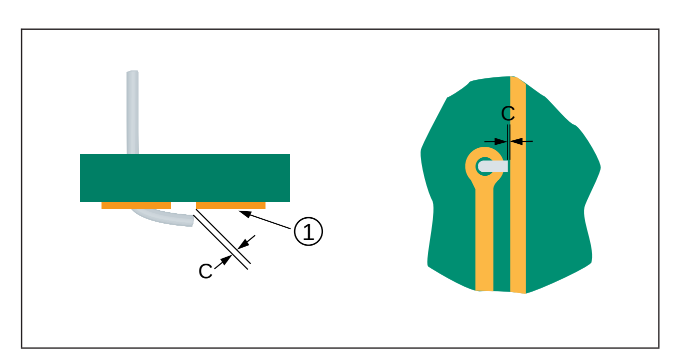


Figure 7-100
1. Noncommon conductor



Figure 7-101

Defect - Class 1,2,3

- The lead is clinched toward an electrically noncommon conductor and violates minimum electrical clearance (C).

7.5.5 Supported Holes – Solder

Criteria for soldered supported holes are provided in 7.5.5.1 through 7.5.5.10.

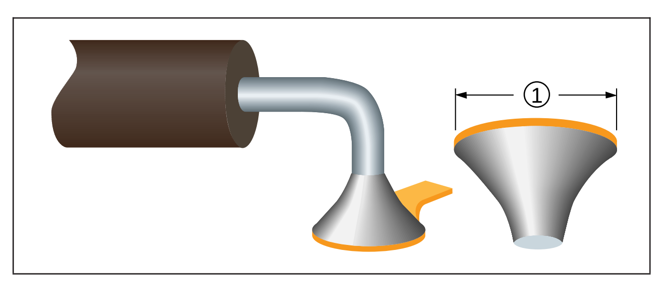


Figure 7-102
1. Land area

Target - Class 1,2,3

- No void areas or surface imperfections.
- Lead and land are well wetted.
- Lead is discernible.
- 100% solder fillet around lead.
- Solder covers lead and feathers out to a thin edge on land/conductor.
- No evidence of fillet lifting (see 5.2.10).



Figure 7-103

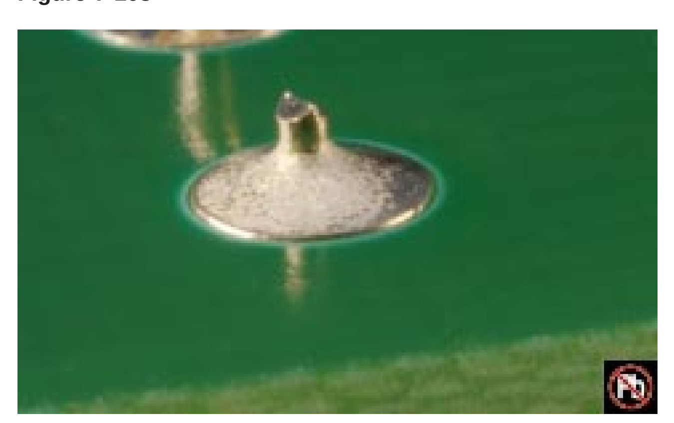


Figure 7-104

Acceptable - Class 1,2,3

- Lead is discernible in the solder.

7.5.5 Supported Holes – Solder (cont.)

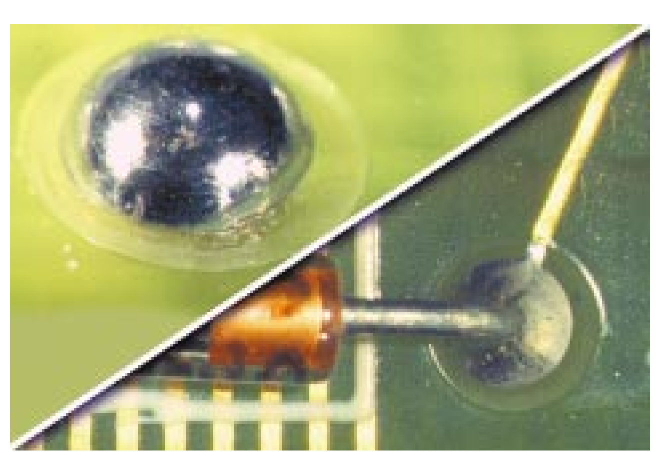


Figure 7-105

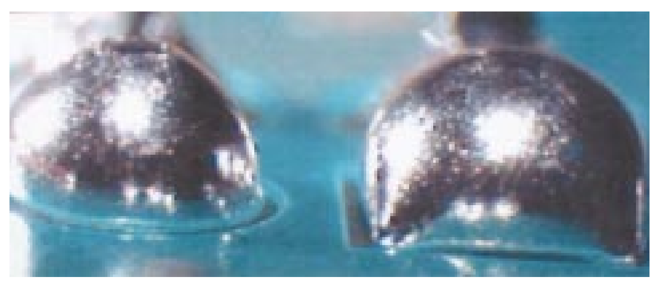


Figure 7-106

Acceptable - Class 1
Process Indicator - Class 2,3

- Fillet convex, and as an exception to Table 7-5, lead not discernible due to excess solder, providing visual evidence of the lead in the hole can be determined on the primary side.
- Fillet is lifted from land on primary side but there is no land damage (not shown) (see 10.2.9.2).

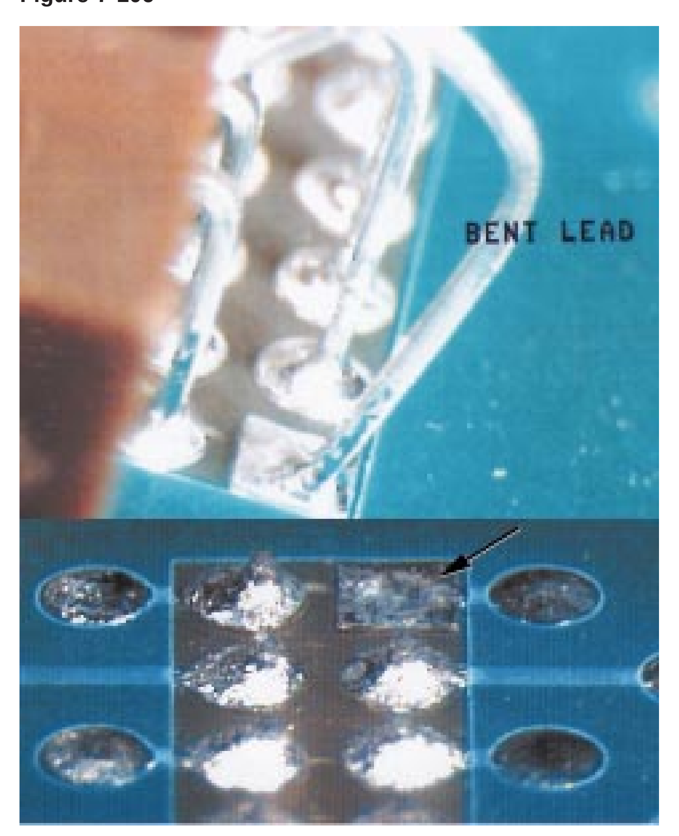


Figure 7-107

Defect - Class 1,2,3

- Lead not discernible due to bent lead.
- Solder not wetted to lead or land.
- Solder coverage does not comply with Tables 7-6 or 7-7.

7.5.5 Supported Holes – Solder (cont.)

Table 7-6 Plated-Through Holes with Component Leads – Minimum Acceptable Solder Conditions[1]

Criteria	Class 1	Class 2	Class 3
A. Vertical fill of solder[2,3] (see 7.5.5.1)	Not Specified	75%	75%
B. Wetting on primary side (solder destination side) of lead and barrel (see 7.5.5.2)	Not Specified	180°	270°
C. Percentage of land area covered with wetted solder on primary side (solder destination side) (see 7.5.5.3)	0	0	0
D. Fillet and wetting on secondary side (solder source side) of lead and barrel (see 7.5.5.4)	270°	270°	330°
E. Percentage of land area covered with wetted solder on secondary side (solder source side) (see 7.5.5.5)	75%	75%	75%

Note 1. Wetted solder refers to solder applied by the solder process.
Note 2. The 25% unfilled height includes both source and destination side depressions.
Note 3. Class 2 may have less than 75% vertical hole fill as noted in 7.5.5.1.

Table 7-7 Plated-Through Holes with Component Leads - Intrusive Soldering Process - Minimum Acceptable Solder Conditions[1]

Criteria	Class 1	Class 2	Class 3
A. Vertical fill of solder [2,3]	Not Specified	75%	75%
B. Wetting on solder destination side of lead and barrel	Not Specified	180°	270°
C. Percentage of land area covered with wetted solder on solder destination side.	0	0	0
D. Wetting on solder source side of lead and barrel[4]	270°	270°	330°
E. Percentage of land area covered with wetted solder on solder source side[4]	75%	75%	75%

Note 1. Wetted solder refers to solder applied by the solder process.
Note 2. The 25% unfilled height includes both source and destination side depressions.
Note 3. Class 2 may have less than 75% vertical hole fill as noted in 7.5.5.1.
Note 4. Applies to any side to which solder paste was applied.

Defect - Class 1,2,3

• Solder connections are not in compliance with Tables 7-6 or 7-7.

7.5.5.1 Supported Holes – Solder – Vertical Fill (A)

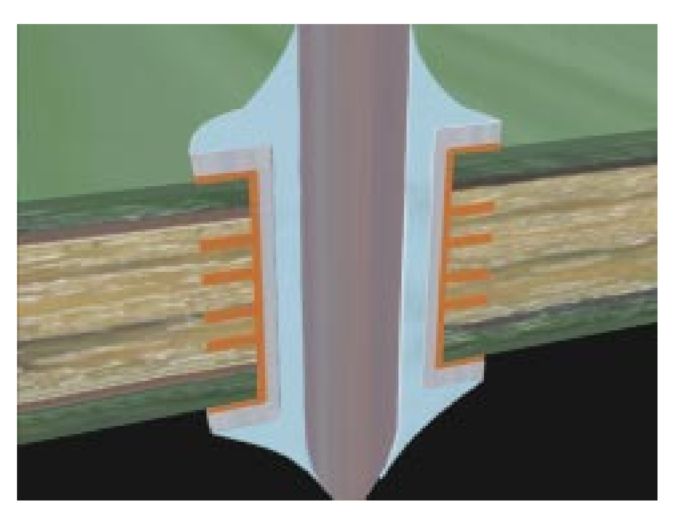


Figure 7-108

Target - Class 1,2,3

- There is 100% fill.

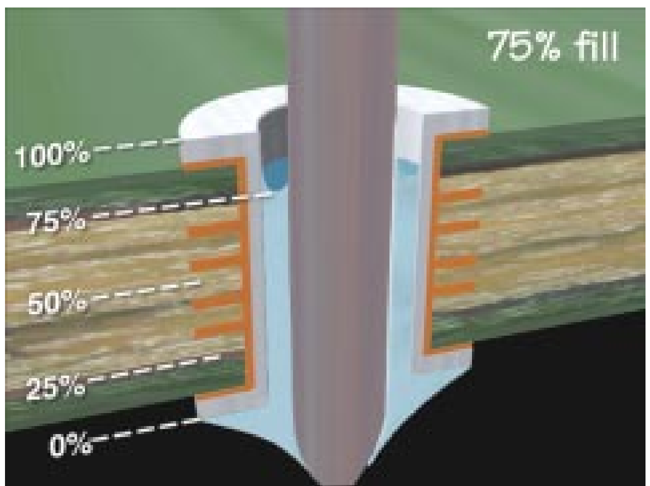
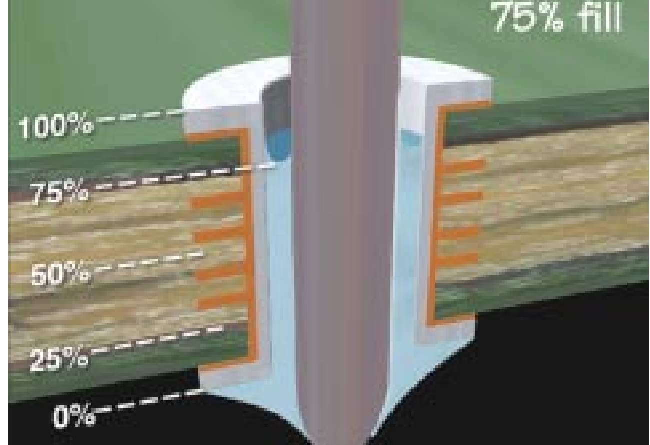



Figure 7-109

Acceptable - Class 1,2,3

- Minimum 75% fill. A maximum of 25% total depression, including both secondary and primary sides is permitted.

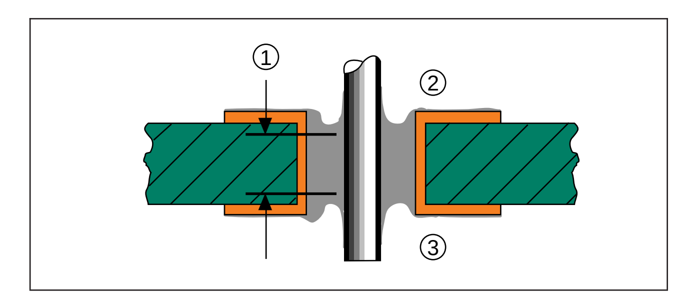


Figure 7-110

1. Vertical fill meets requirements of Table 7-6
2. Solder destination side
3. Solder source side

Defect - Class 2,3

- Vertical fill of hole is less than 75%.

7.5.5.1 Supported Holes – Solder – Vertical fill (A) (cont.)

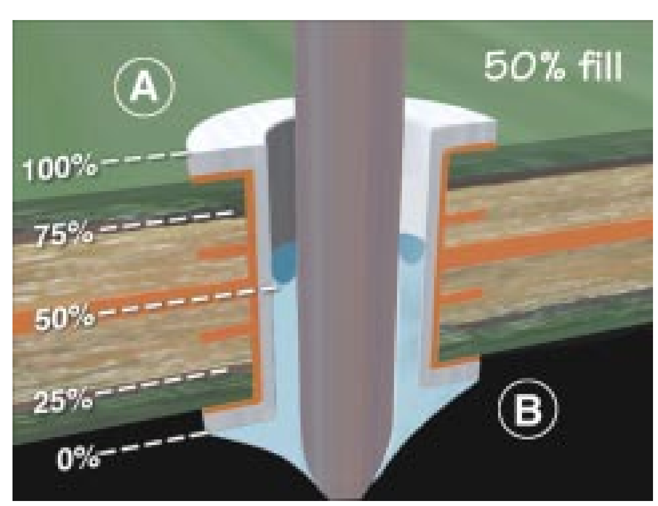


Figure 7-111

Not Specified - Class 1
Acceptable - Class 2
Defect - Class 3

- As an exception to the fill requirements of Tables 7-6 or 7-7, a 50% vertical fill of a PTH is permitted for Class 2 products provided the following conditions are met:
  - The PTH is connected to thermal or conductor planes that act as thermal heat sinks.
  - The component lead is discernible in the Side B solder connection of Figure 7-111.
  - The solder fillet on Side B of Figure 7-111 has wetted 360° of the PTH barrel wall and 360° of the lead.
  - Surrounding PTHs meet requirements of Tables 7-6 or 7-7.

Note: Less than 100% solder fill may not be acceptable in some applications, e.g., thermal shock. The user is responsible for identifying these situations to the manufacturer.

7.5.5.2 Supported Holes – Solder – Primary Side – Lead to Barrel (B)



Figure 7-112

Target - Class 1,2,3

- 360° wetting present on lead and barrel.

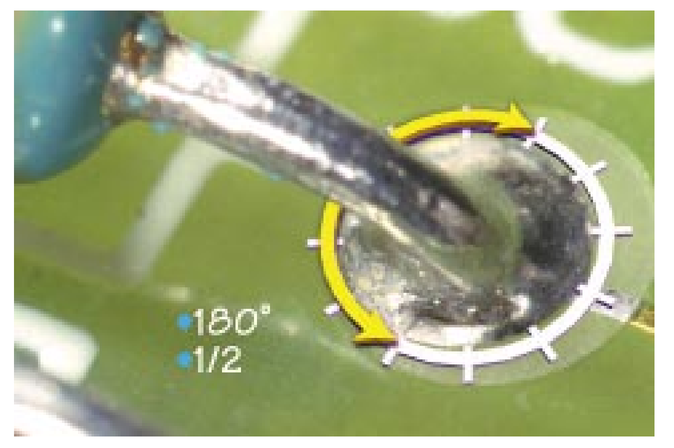


Figure 7-113

Not Specified - Class 1
Acceptable - Class 2

- Minimum 180° wetting present on lead and barrel, Figure 7-113.

Acceptable - Class 3

- Minimum 270° wetting present on lead and barrel, Figure 7-114.

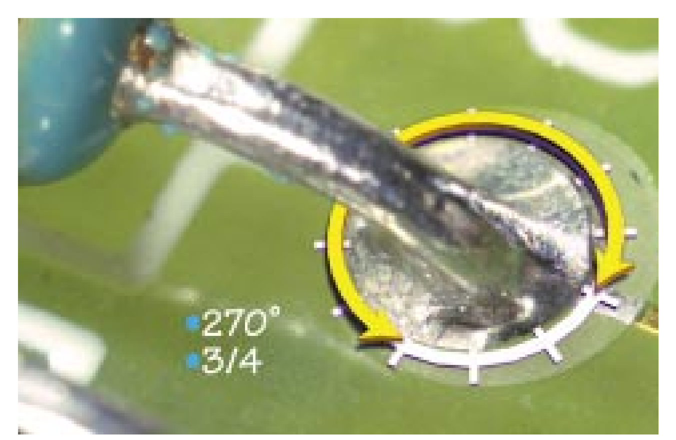


Figure 7-114

7.5.5.2 Supported Holes – Solder – Primary Side – Lead to Barrel (B) (cont.)




Figure 7-115

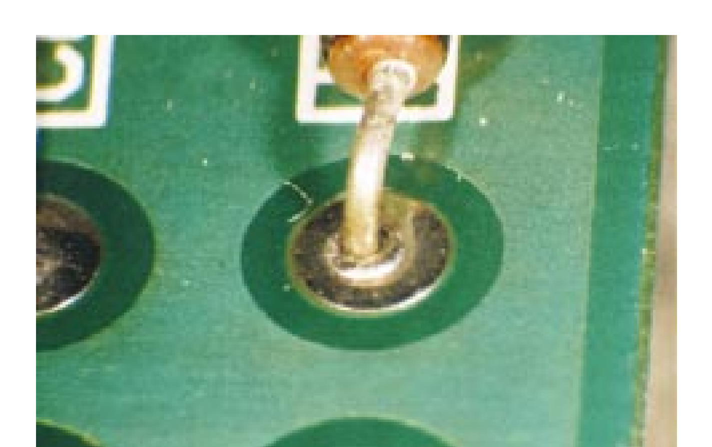


Figure 7-116

Defect - Class 2

- Less than 180° wetting on lead or barrel.

Defect - Class 3

- Less than 270° wetting on lead or barrel.

7.5.5.3 Supported Holes – Solder – Primary Side – Land Area Coverage (C)

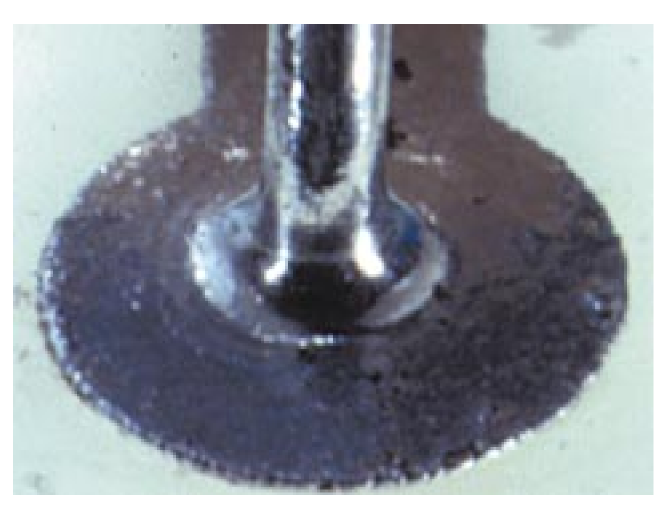


Figure 7-117

Acceptable - Class 1,2,3

- The land area does not need to be wetted with solder on the primary side.

7.5.5.4 Supported Holes – Solder – Secondary Side – Lead to Barrel (D)

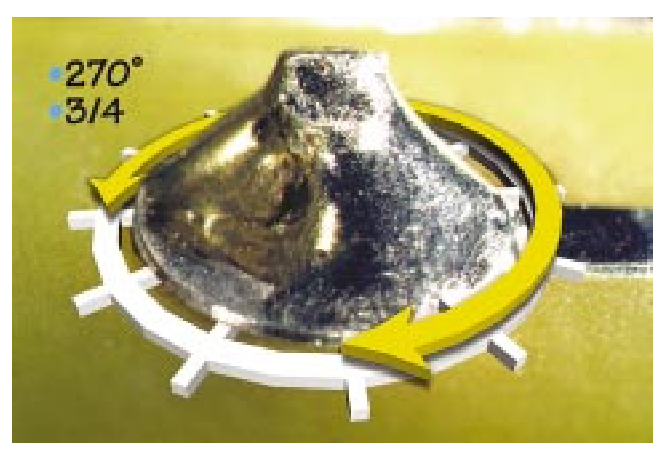


Figure 7-118

Acceptable - Class 1,2

- Minimum 270° fillet and wetting (lead, barrel and termination area).

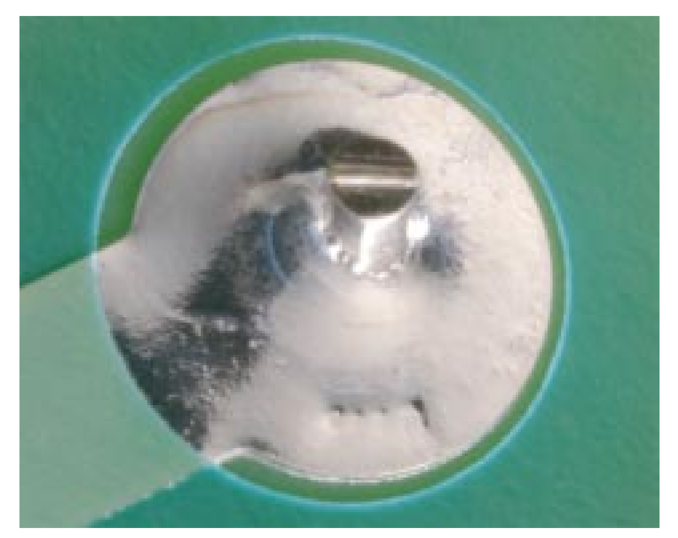


Figure 7-119

Acceptable - Class 3

- Minimum 330° fillet and wetting (lead, barrel and termination area). (Not Shown.)

Defect - Class 1,2,3

- Does not meet requirements of Tables 7-6 or 7-7.

7.5.5.5 Supported Holes – Solder – Secondary Side – Land Area Coverage (E)



Figure 7-120

Target - Class 1,2,3

- Land area completely covered on the secondary side.

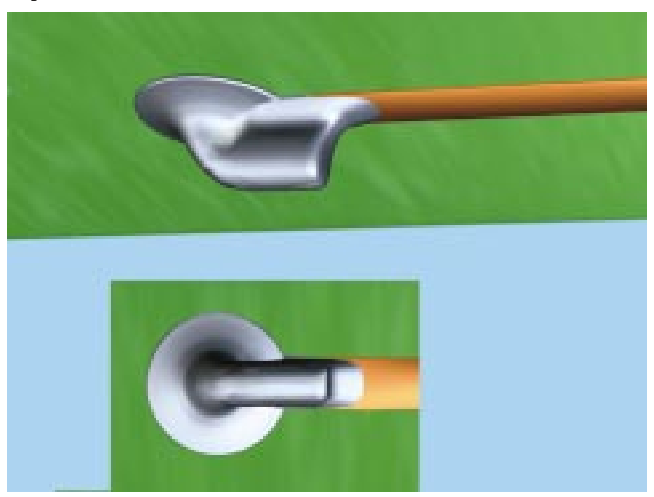


Figure 7-121



Figure 7-122

Acceptable - Class 1,2,3

- Minimum 75% of land area covered with wetted solder on the secondary side.

Defect - Class 1,2,3

- Does not meet requirements of Tables 7-6 or 7-7.

7.5.5.6 Supported Holes – Solder Conditions – Solder in Lead Bend

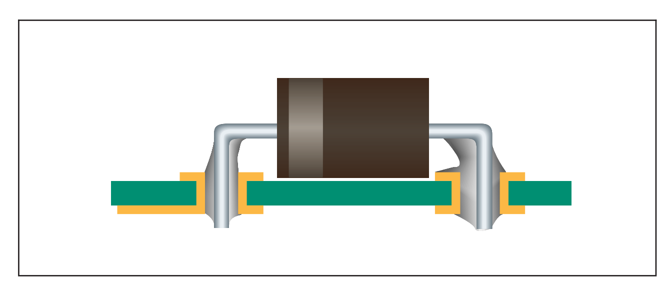


Figure 7-123



Figure 7-124

Acceptable - Class 1,2,3

- Solder in lead bend area does not contact the component body.

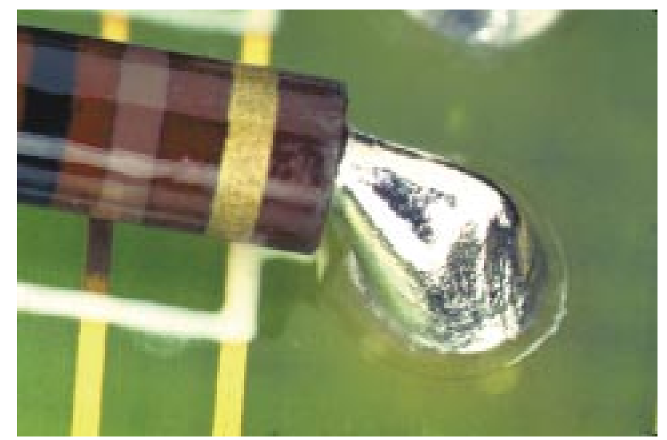


Figure 7-125

Defect - Class 1,2,3

- Solder in bend area comes in contact with the component body or end seal.

7.5.5.7 Supported Holes – Solder Conditions – Meniscus in Solder

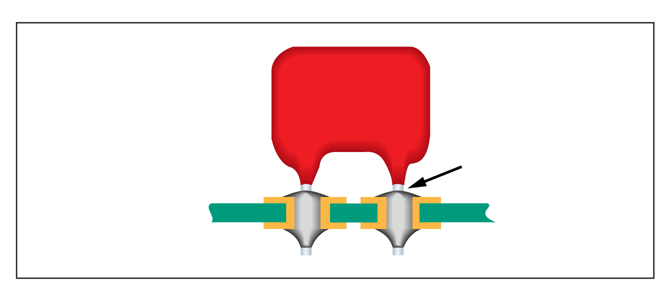


Figure 7-126

Target - Class 1,2,3

- There is 1.2 mm [0.048 in] separation between the coating meniscus and the solder fillet.

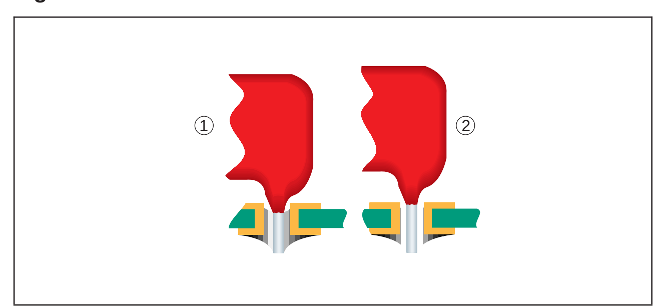


Figure 7-127
1. Class 1
2. Class 2,3

Acceptable Class 1

- Components with a coating meniscus can be mounted with the meniscus into the solder provided:
  - 360° wetting on the secondary side.
  - Lead coating meniscus is not discernible within the connection on the secondary side.

Acceptable Class 2,3

- Coating meniscus is not in the plated through hole and there is discernible clearance between the meniscus and the solder fillet.

Process Indicator - Class 2

- Coating meniscus is in the plated through hole but solder joint meets the requirements of Table 7-6 or 7-7.

Defect - Class 1,2,3

- Does not exhibit good wetting on secondary side.

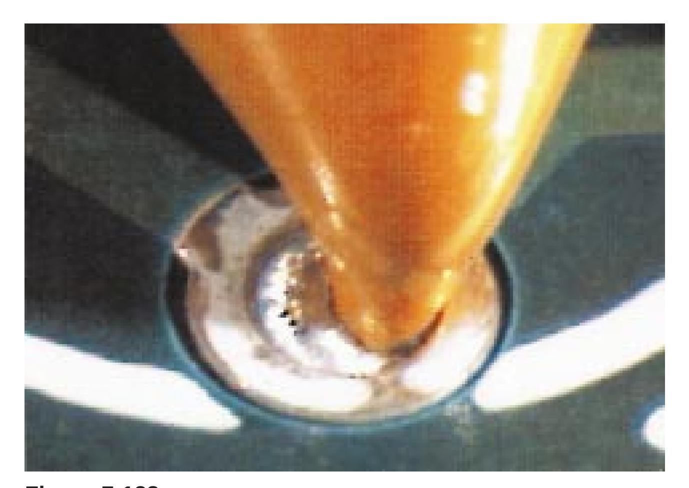


Figure 7-128

Defect - Class 3

- Does not meet requirements of Tables 7-6 or 7-7.
- Coating meniscus is in the plated through hole.
- Coating meniscus is embedded in the solder connection.

Note: When required for certain applications, meniscus on the components are to be controlled to ensure that, with components fully seated, the meniscus on the leads does not enter the plated-through holes of the assembly. (Example: high frequency applications, very thin PCBs.)

7.5.5.8 Lead Cutting after Soldering

The following criteria apply to printed board assemblies where the connections have been trimmed after soldering. Leads may be trimmed after soldering provided the cutters do not damage the component or solder connection due to physical shock. When lead cutting is performed after soldering, the solder terminations are to be visually inspected at 10X to ensure that the original solder connection has not been damaged, i.e., fractured or deformed. As an alternative to visual inspection, the solder connections may be reflowed. If the solder connection is reflowed this is considered part of the soldering process and is not to be considered rework. This requirement is not intended to apply to components which are designed such that a portion of the lead is intended to be removed after soldering, i.e., break away tie bars).

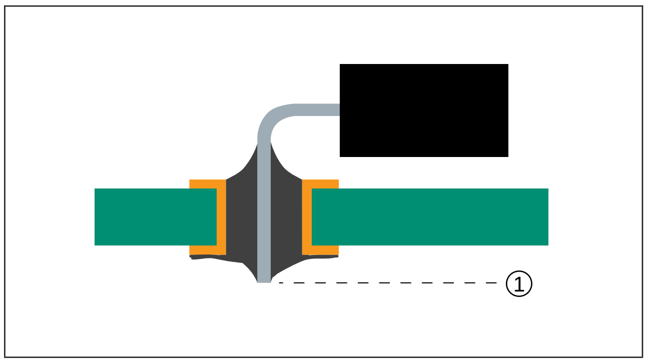


Figure 7-129
1. Lead protrusion

Acceptable - Class 1,2,3

- No fractures between lead and solder.
- Lead protrusion within specification.

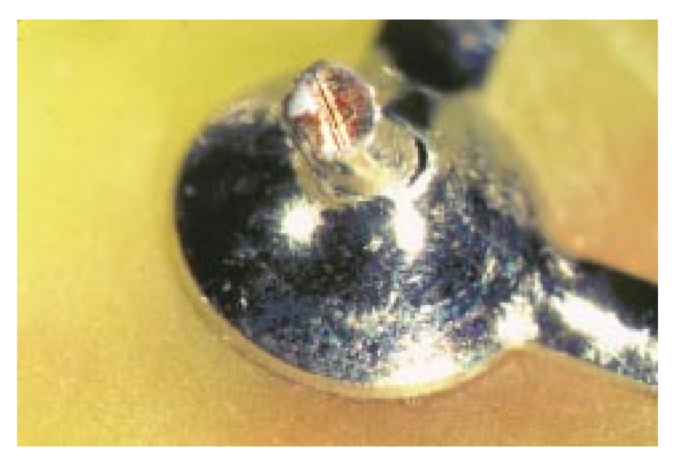


Figure 7-130

Defect - Class 1,2,3

- Evidence of fracture between lead and solder fillet.

7.5.5.9 Supported Holes – Coated Wire Insulation in Solder

These requirements apply when the solder connection meets the minimum requirements of Tables 7-6 or 7-7. See 6.8 for extruded insulation requirements.

This section applies to coatings that may extend into the connection during soldering operations, provided the material is not corrosive.



Figure 7-131

Target - Class 1,2,3

- Clearance of one wire diameter between solder fillet and insulation.



Figure 7-132

Acceptable - Class 1,2
Process Indicator - Class 3

- Coating is entering solder connection on primary side but exhibits all around good wetting on secondary side.
- Coating is not discernible on secondary side.

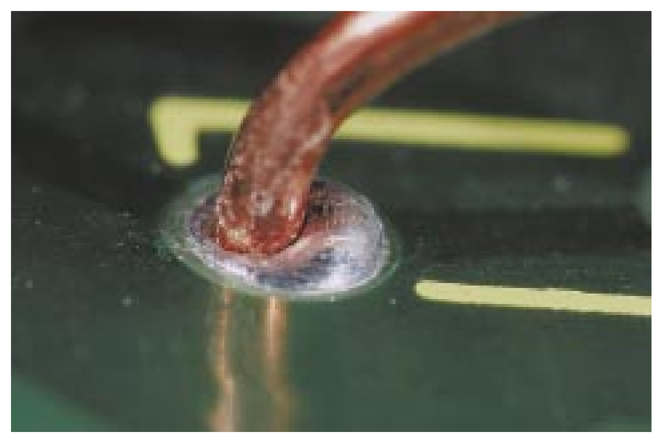


Figure 7-133

Defect - Class 1,2,3

- Solder connection exhibits poor wetting and does not meet the minimum requirements of Tables 7-6 or 7-7.
- Coating is discernible on secondary side.

7.5.5.10 Supported Holes – Interfacial Connection without Lead – Vias

Plated-through holes used for interfacial connection not exposed to solder because of permanent or temporary masks need not be filled with solder. Plated-through holes or vias without leads, after exposure to wave, dip or drag soldering equipment are to meet these acceptability requirements.

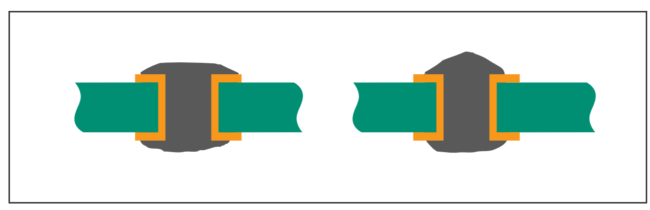


Figure 7-134

Target - Class 1,2,3

- Holes are completely filled with solder.
- The tops of lands show good wetting.

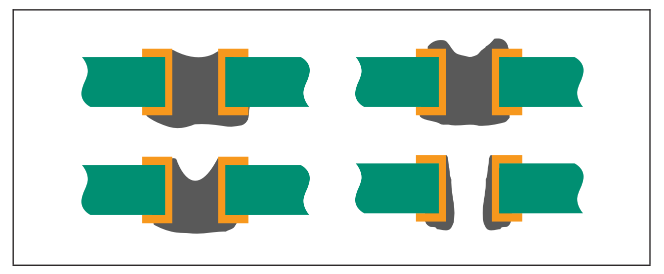


Figure 7-135

Acceptable - Class 1,2,3

- Sides of holes are wetted with solder.

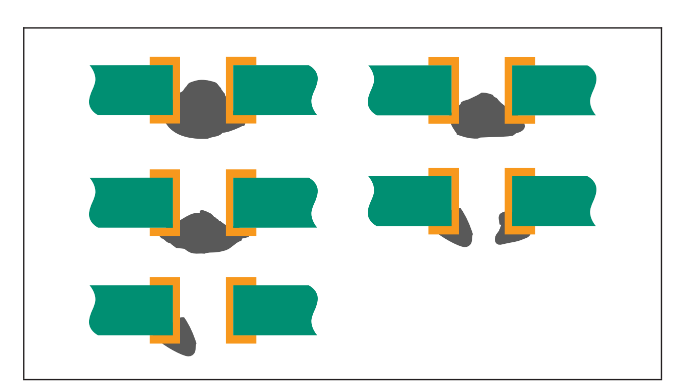


Figure 7-136

Acceptable - Class 1
Process Indicator - Class 2,3

- Solder has not wetted side of holes.

Note: There is no defect condition for this.

Note: Solder capped PTHs have the possibility of entrapping contaminants that are difficult to remove if cleaning is required.

8 Surface Mount Assemblies

This section covers acceptability requirements for the fabrication of surface mount assemblies.

In this Standard, the words ‘‘plastic component’’ are used in the generic sense to differentiate between plastic components and those made of other materials, e.g., ceramic/alumina or metal (normally hermetically sealed).

Some dimensions, e.g., solder thickness, are not inspectable conditions and are identified by notes.

Dimension (G) is the solder fillet from the top of the land to the bottom of the termination. Dimension (G) is the prime parameter in the determination of solder connection reliability for leadless components. A thick (G) is desirable. Additional information related to reliability of surface mount connections is available in IPC-D-279, IPC-SM-785 and IPC-9701.

In addition to the criteria in this section, solder connections must meet the criteria of Section 5.

8 Surface Mount Assemblies (cont.)

The following topics are addressed in this section:

8.1 Staking Adhesive

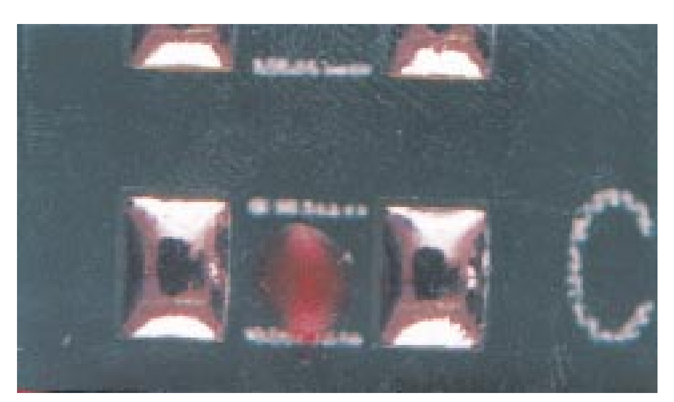


Figure 8-1

Target - Class 1,2,3

- No adhesive present on solderable surfaces of the termination area.
- Adhesive is centered between the lands.

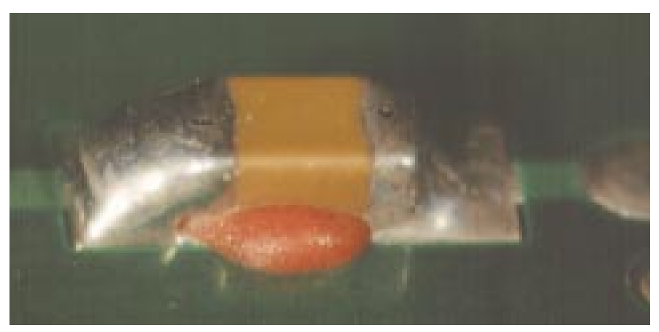


Figure 8-2

Acceptable - Class 1
Process Indicator - Class 2

- Adhesive material extending from under the component is visible in the termination area, but end joint width meets minimum requirements.

Defect - Class 3

- Adhesive materials extending from under the component are visible in the termination area.

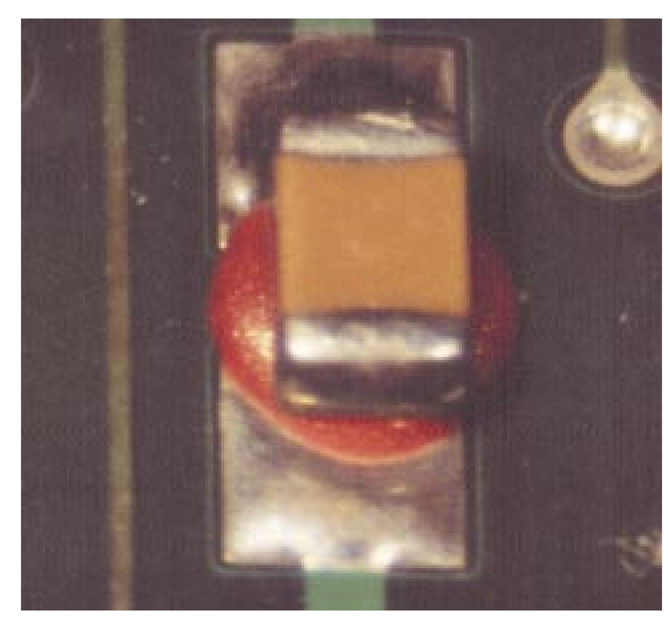


Figure 8-3

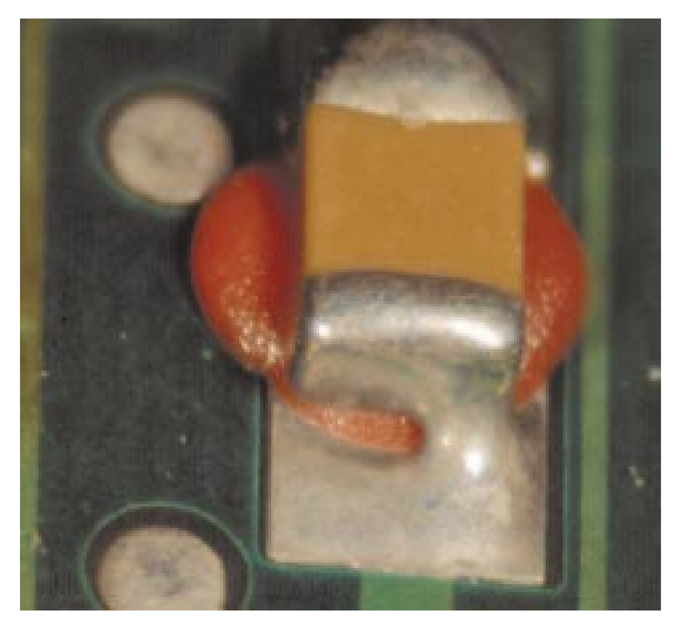


Figure 8-4

8.2 SMT Connections

SMT connections must meet the criteria of 8.2.1 through 8.2.14, as appropriate.

8.2.1 Chip Components – Bottom Only Terminations

Discrete chip components, leadless chip carriers, and other devices that have metal terminations on the bottom side only must meet the dimensional and solder fillet requirements listed below for each product classification. The widths of the component and land are (W) and (P), respectively, and the termination overhang describes the condition where the smaller extends beyond the larger termination (i.e., W or P).

Table 8-1 Dimensional Criteria - Chip Component - Bottom Only Termination Features

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) or 50% (P), whichever is less; Note 1		25% (W) or 25% (P), whichever is less; Note 1
End Overhang	B	Not permitted		
Minimum End Joint Width	C	50% (W) or 50% (P), whichever is less		75% (W) or 75% (P), whichever is less
Minimum Side Joint Length	D	Note 3		
Maximum Fillet Height	E	Note 3		
Minimum Fillet Height	F	Note 3		
Solder Thickness	G	Note 3		
Minimum End Overlap	J	Required		
Termination Length	L	Note 2		
Land Width	P	Note 2		
Termination Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size, determined by design.
Note 3. Wetting is evident.

8.2.1.1 Chip Components – Bottom Only Terminations, Side Overhang (A)

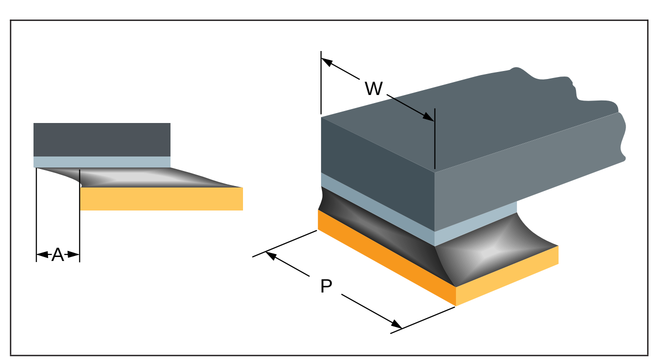


Figure 8-5

Target - Class 1,2,3

- No side overhang.

Acceptable - Class 1,2

- Side overhang (A) is less than or equal to 50% width of component termination area (W) or 50% width of land (P), whichever is less.

Acceptable - Class 3

- Side overhang (A) is less than or equal to 25% width of component termination area (W) or 25% width of land (P), whichever is less.

Defect - Class 1,2

- Side overhang (A) is greater than 50% component termination width (W) or 50% land width (P), whichever is less.

Defect - Class 3

- Side overhang (A) is greater than 25% component termination width (W) or 25% land width (P), whichever is less.

8.2.1.2 Chip Components – Bottom Only Terminations, End Overhang (B)

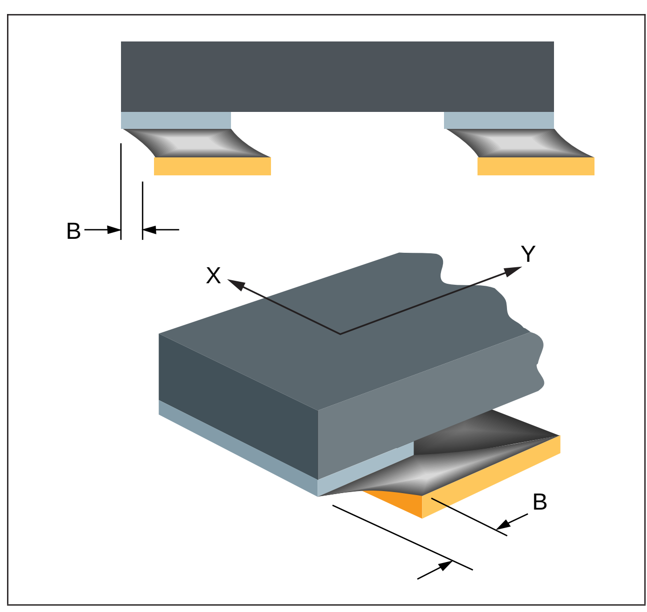


Figure 8-6

Defect - Class 1,2,3

- End overhang (B) in Y axis is not permitted.

8.2.1.3 Chip Components – Bottom Only Terminations, End Joint Width (C)

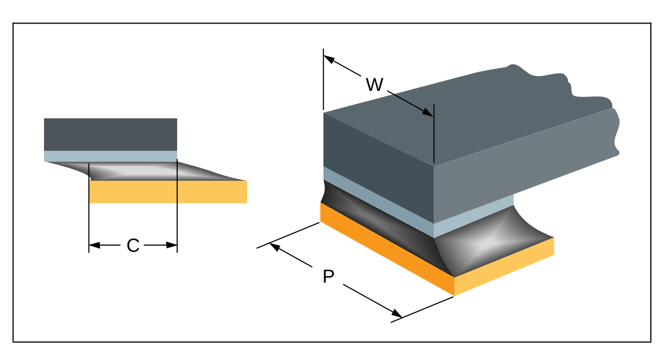


Figure 8-7

Target - Class 1,2,3

- End joint width (C) is equal to the width of the component termination (W) or width of land (P), whichever is less.

Acceptable - Class 1,2

- Minimum end joint width (C) is 50% width of component termination (W) or 50% width of land (P), whichever is less.

Acceptable - Class 3

- Minimum end joint width (C) is 75% width of component termination (W) or 75% width of land (P), whichever is less.

Defect - Class 1,2

- End joint width (C) is less than 50% width of component termination (W) or less than 50% width of land (P), whichever is less.

Defect - Class 3

- End joint width (C) is less than 75% width of component termination (W) or less than 75% width of land (P), whichever is less.

8.2.1.4 Chip Components – Bottom Only Terminations, Side Joint Length (D)

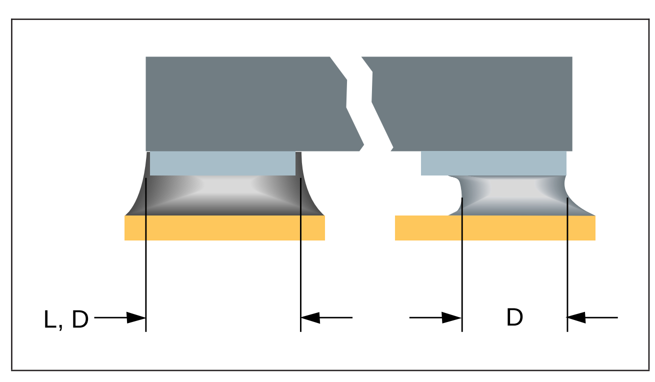


Figure 8-8

Target - Class 1,2,3

- Side joint length (D) equals component termination length (L).

Acceptable - Class 1,2,3

- Any side joint length (D) is acceptable if all other solder requirements are met.

8.2.1.5 Chip Components – Bottom Only Terminations, Maximum Fillet Height (E)

Maximum fillet height (E) requirements are not specified for Class 1,2,3.

8.2.1.6 Chip Components – Bottom Only Terminations, Minimum Fillet Height (F)

Minimum fillet height (F) requirements are not specified for Class 1,2,3. However, a wetted fillet is evident.

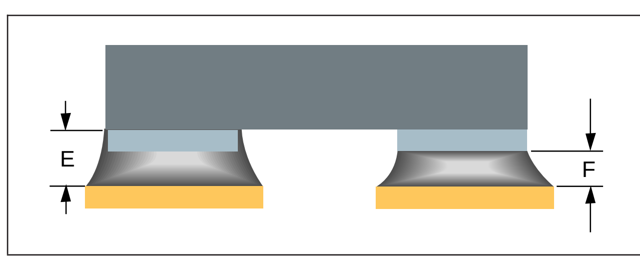


Figure 8-9

Defect - Class 1,2,3

• No wetting evident.

8.2.1.7 Chip Components – Bottom Only Terminations, Solder Thickness (G)

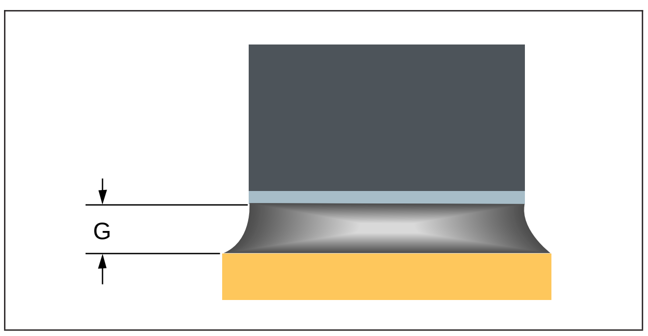


Figure 8-10

Acceptable - Class 1,2,3

- Wetting is evident.

Defect - Class 1,2,3

- No wetting evident.

8.2.1.8 Chip Components – Bottom Only Terminations, End Overlap (J)

Acceptable - Class 1,2,3

- Evidence of overlap contact (J) between the component termination and the land is required.

Defect - Class 1,2,3

- Insufficient end overlap.

8.2.2 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination

These criteria apply to component types such as chip resistor, chip capacitor, and square end MELF.

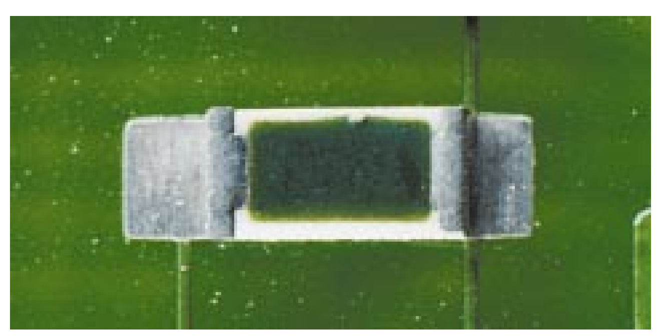
Solder connections to components having terminations of a square or rectangular configuration must meet the dimensional and solder fillet requirements listed below for each product classification. For 1 sided termination, the solderable side is the vertical end face of the component.

Table 8-2 Dimensional Criteria - Chip Components - Rectangular or Square End Components - 1, 3 or 5 Side Termination

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) or 50% (P), whichever is less; Note 1		25% (W) or 25% (P), whichever is less; Note 1
End Overhang	B	Not permitted		
Minimum End Joint Width	C	50% (W) or 50% (P), whichever is less; Note 5		75% (W) or 75% (P), whichever is less; Note 5
Minimum Side Joint Length	D	Note 3		
Maximum Fillet Height	E	Note 4		
Minimum Fillet Height	F	Wetting is evident on the vertical surface(s) of the component termination. Note 6		(G) + 25% (H) or (G) + 0.5 mm [0.02 in], whichever is less. Note 6
Solder Thickness	G	Note 3		
Termination Height	H	Note 2		
Minimum End Overlap	J	Required		
Width of Land	P	Note 2		
Termination Width	W	Note 2		
Side Mounting/Billboarding, Notes 7, 8				
Width to Height Ratio		Does not exceed 2:1		
End Cap and Land Wetting		100% wetting land to end metallization contact areas		
Minimum End Overlap	J	100%		
Maximum Side Overhang	A	Not permitted		
End Overhang	B	Not permitted		
Maximum Component Size		No limits		1206
Termination Faces		Three or more faces		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. The maximum fillet may overhang the land and/or extend onto the top of the end cap metallization; however, the solder does not extend further onto the top of the component body.
Note 5: (C) is measured from the narrowest side point of the solder fillet.
Note 6: Designs with via in pad may preclude meeting these criteria. Solder acceptance criteria should be defined between the user and the manufacturer.
Note 7: These criteria are for chip components that may flip (rotate) onto the narrow edge during assembly.
Note 8: These criteria may not be acceptable for certain high frequency or high vibration applications.

8.2.2.1 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Side Overhang (A)


Figure 8-11

Target - Class 1,2,3

• No side overhang.

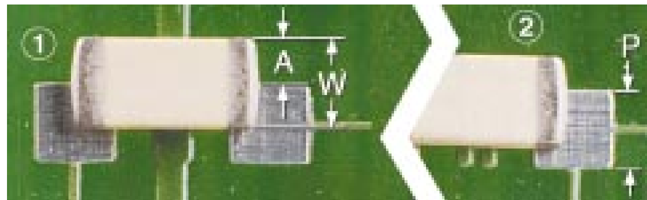


Figure 8-12
1. Class 2
2. Class 3

Acceptable - Class 1,2

• Side overhang (A) is less than or equal to 50% width of component termination area (W) or 50% width of land (P), whichever is less.

Acceptable - Class 3

• Side overhang (A) is less than or equal to 25% width of component termination area (W) or 25% width of land (P), whichever is less.

8.2.2.1 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Side Overhang (A) (cont.)

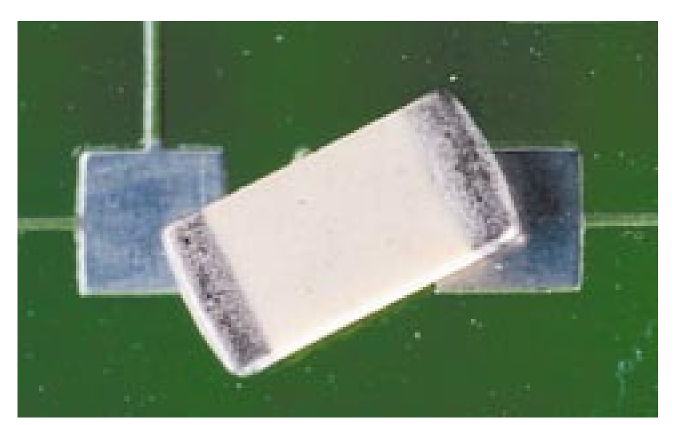


Figure 8-13

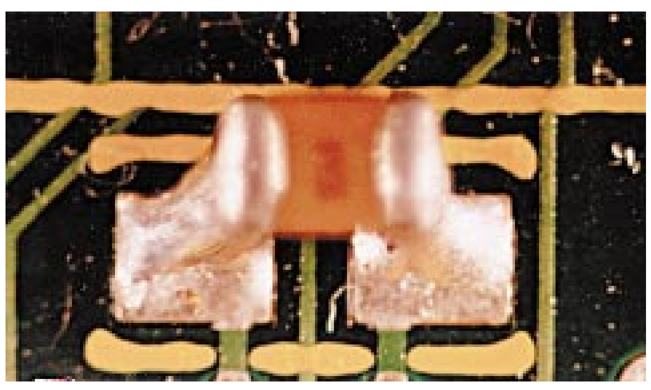


Figure 8-14

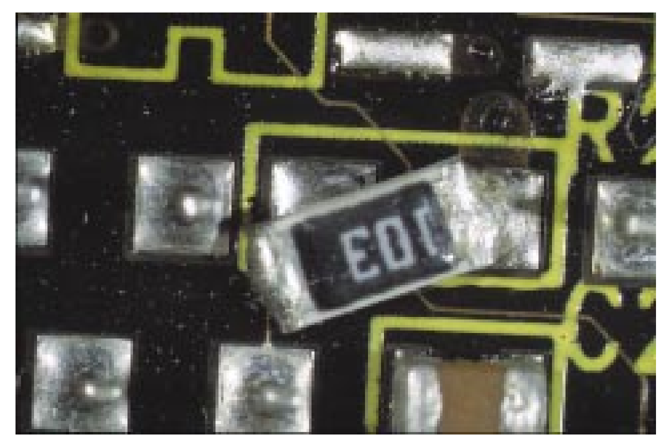


Figure 8-15

Defect - Class 1,2

- Side overhang (A) is greater than 50% component termination width (W) or 50% land width (P), whichever is less.

Defect - Class 3

- Side overhang (A) is greater than 25% component termination width (W) or 25% land width (P), whichever is less.

8.2.2.2 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, End Overhang (B)

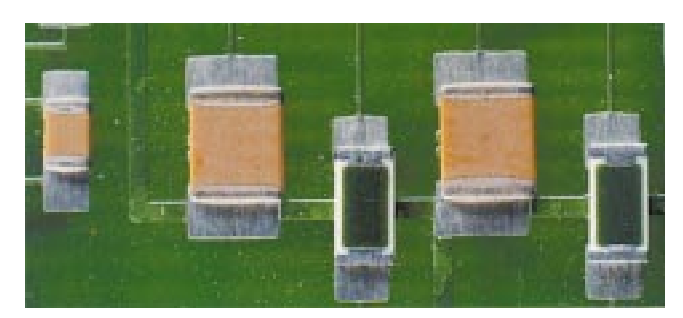


Figure 8-16

Target - Class 1,2,3

• No end overhang.

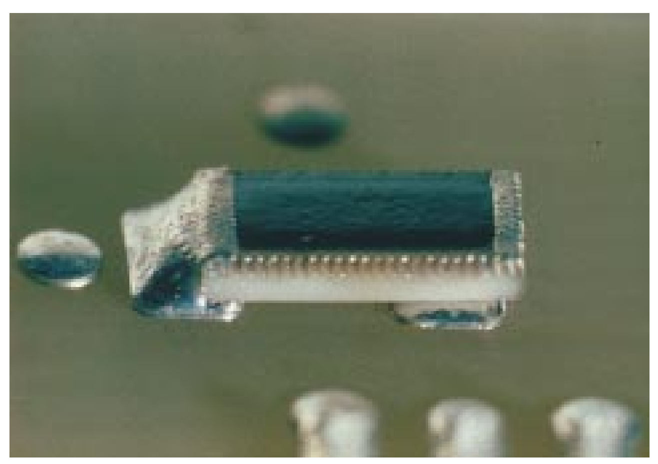


Figure 8-17

Defect - Class 1,2,3

• Termination overhangs land.

8.2.2.3 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, End Joint Width (C)

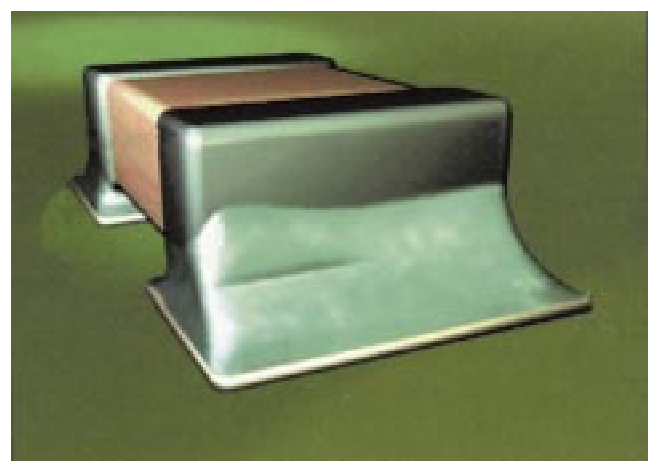


Figure 8-18

Target - Class 1,2,3

• End joint width is equal to component termination width or width of land, whichever is less.

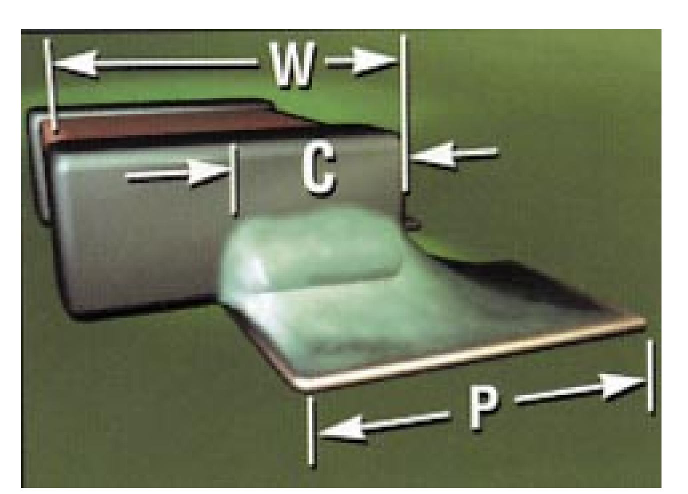


Figure 8-19

Acceptable - Class 1,2

• End joint width (C) is minimum 50% of component termination width (W) or 50% land width (P), whichever is less.

8.2.2.3 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, End Joint Width (C) (cont.)

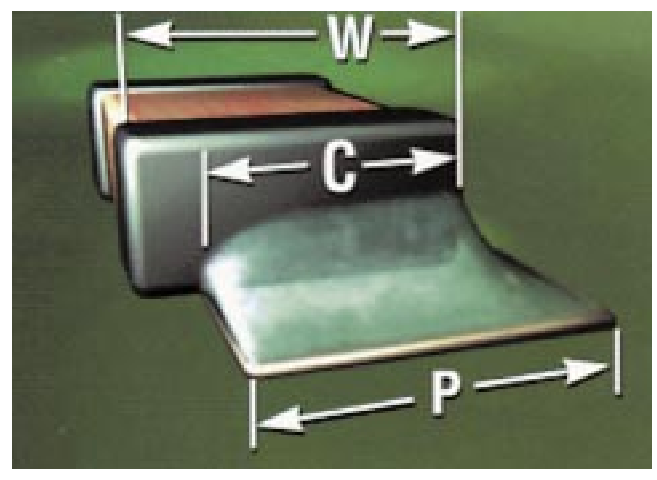


Figure 8-20

Acceptable - Class 3

- End joint width (C) is minimum 75% of component termination (W) or 75% land width (P), whichever is less.

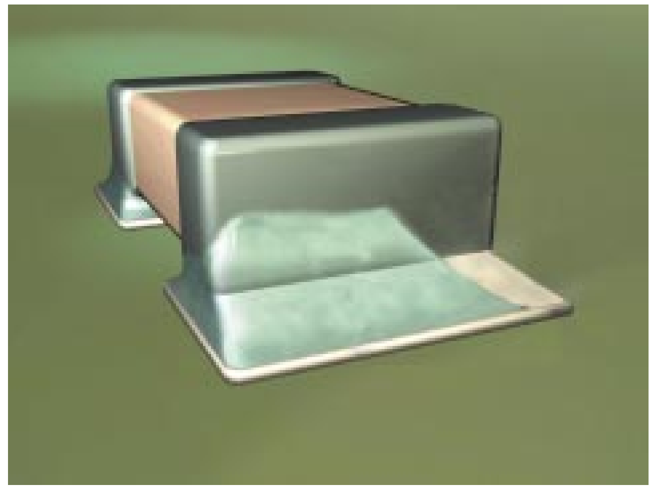


Figure 8-21

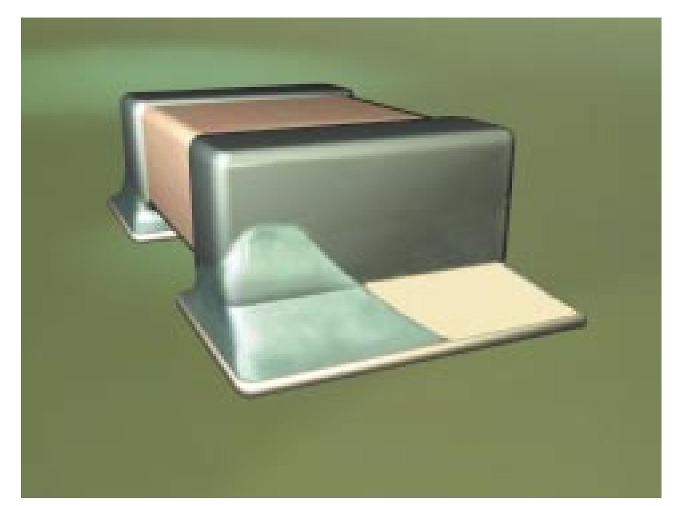


Figure 8-22

Defect - Class 1,2,3

- Less than minimum acceptable end joint width.

8.2.2.4 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Side Joint Length (D)

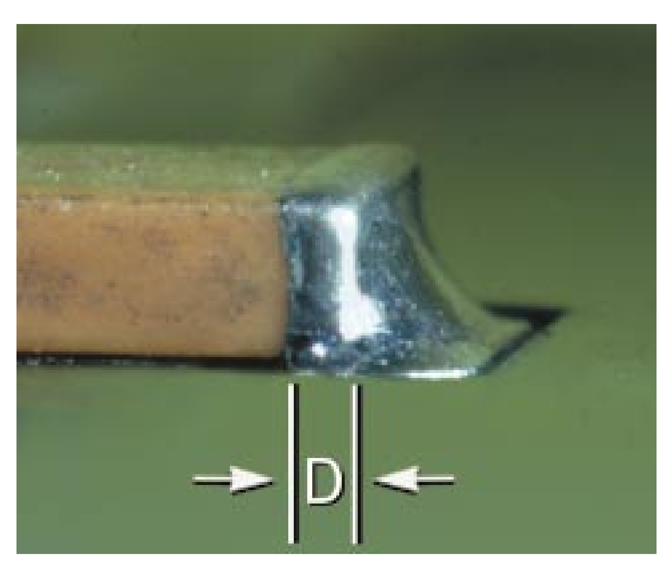


Figure 8-23

Target - Class 1,2,3

- Side joint length equals length of component termination.

Acceptable - Class 1,2,3

- Side joint length is not required. However, a wetted fillet is evident.

Defect - Class 1,2,3

- No wetted fillet.

8.2.2.5 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Maximum Fillet Height (E)

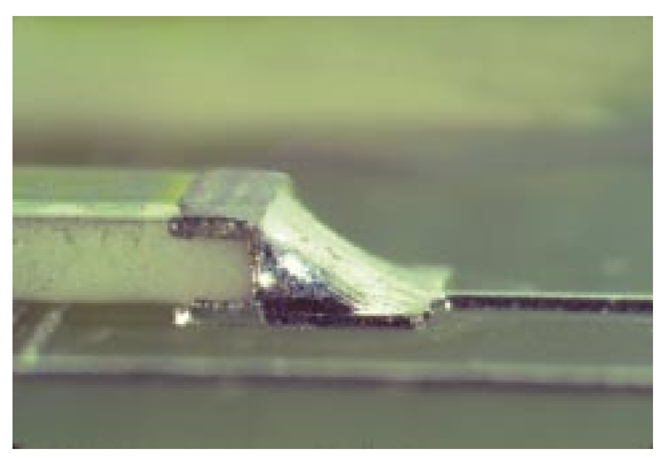


Figure 8-24

Target - Class 1,2,3

- Maximum fillet height is the solder thickness plus component termination height.

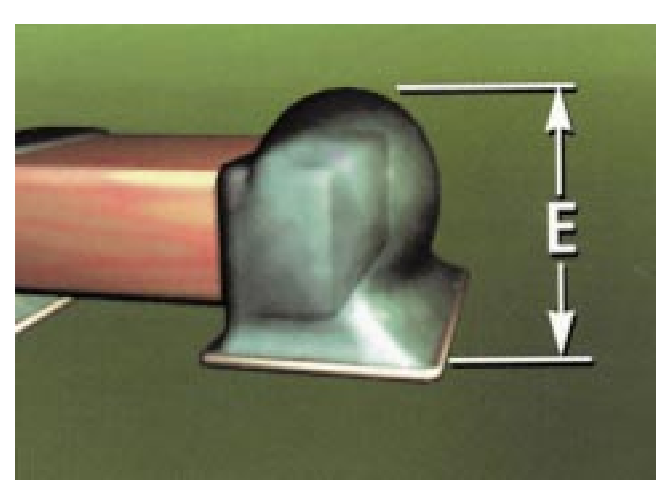


Figure 8-25

Acceptable - Class 1,2,3

- Maximum fillet height (E) may overhang the land and/or extend onto the top of the end cap metallization, but not extend further onto the top of component body.

Defect - Class 1,2,3

- Solder fillet extends onto the top of the component body.

8.2.2.6 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Minimum Fillet Height (F)

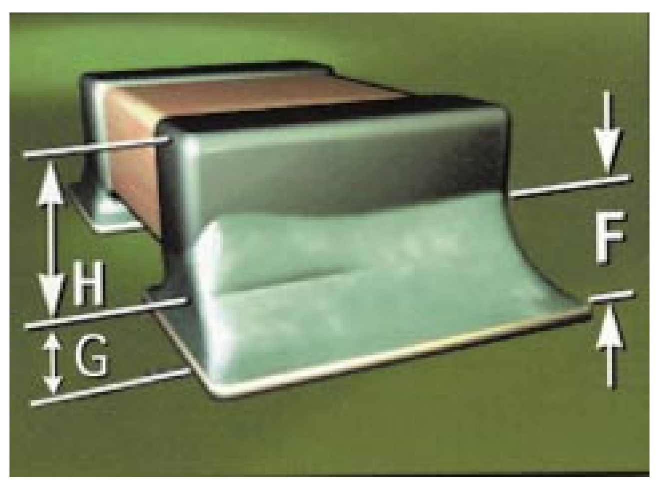


Figure 8-26

Acceptable - Class 1,2

- Wetting is evident on the vertical surface(s) of the component termination.

Acceptable - Class 3

- Minimum fillet height (F) is solder thickness (G) plus 25% termination height (H), or 0.5 mm [0.02 in], whichever is less.

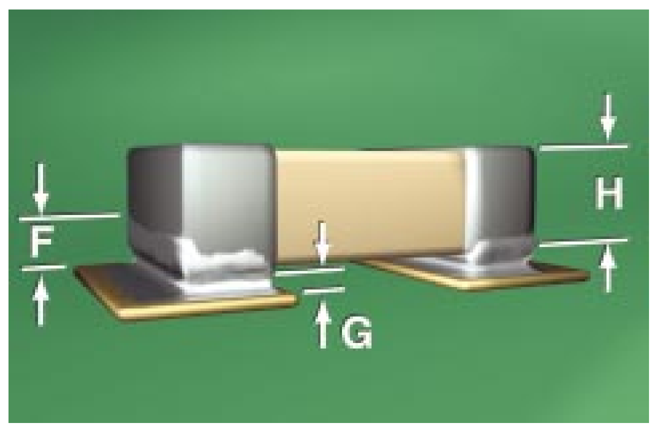


Figure 8-27

Defect - Class 1,2

- No fillet height evident on face of component.

Defect - Class 3

- Minimum fillet height (F) is less than solder thickness (G) plus 25% (H), or solder thickness (G) plus 0.5 mm [0.02 in], whichever is less.

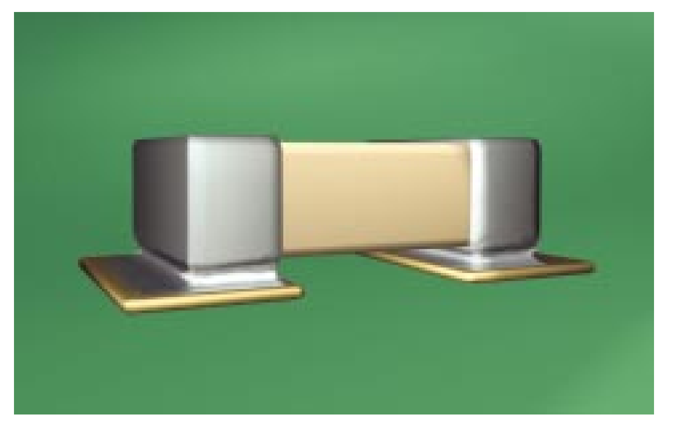


Figure 8-28

Defect - Class 1,2,3

- Insufficient solder.
- A wetted fillet is not evident.

8.2.2.7 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Thickness (G)

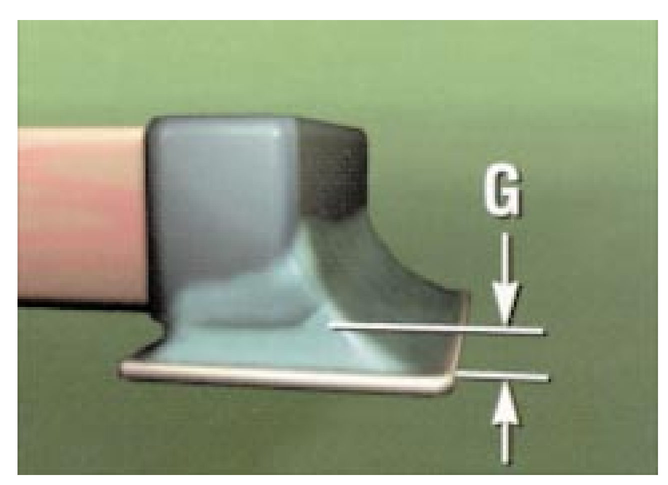


Figure 8-29

Acceptable - Class 1,2,3

• Wetted fillet evident.

Defect - Class 1,2,3

• No wetted fillet.

8.2.2.8 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, End Overlap (J)

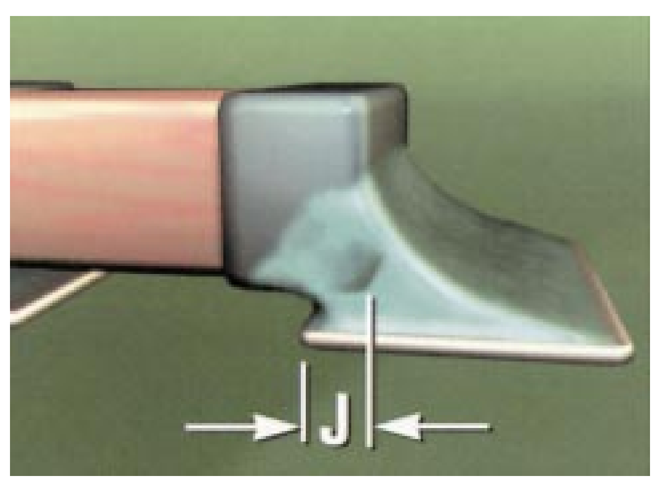


Figure 8-30

Acceptable - Class 1,2,3

- Evidence of overlap contact (J) between the component termination and the land is required.



Figure 8-31

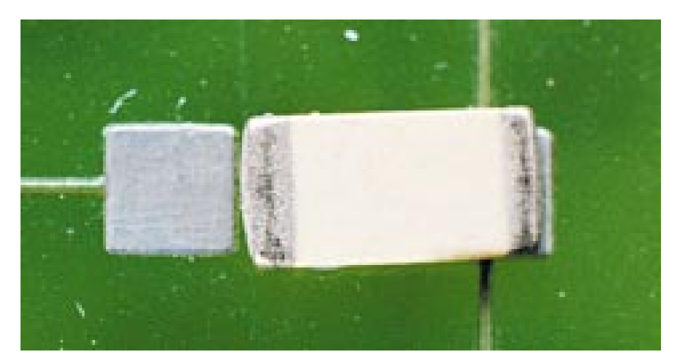


Figure 8-32

Defect - Class 1,2,3

- Insufficient end overlap.

8.2.2.9 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Termination Variations

8.2.2.9.1 Chip Components – Termination Variations – Mounting on Side (Billboarding)

This section provides criteria for chip components that may flip (rotate) onto the narrow edge during assembly.

These criteria may not be acceptable for certain high frequency or high vibration applications.

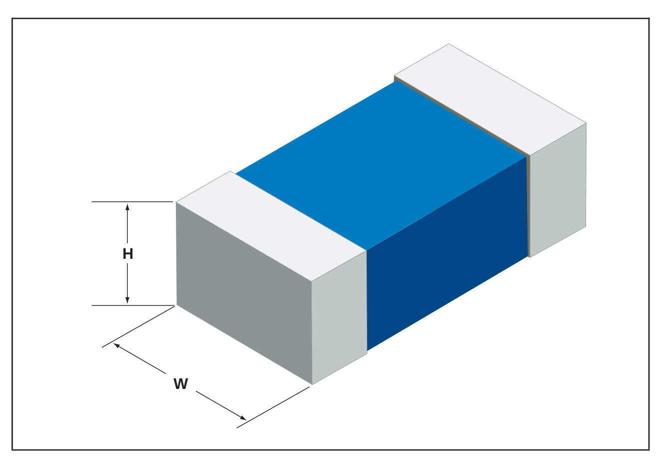


Figure 8-33

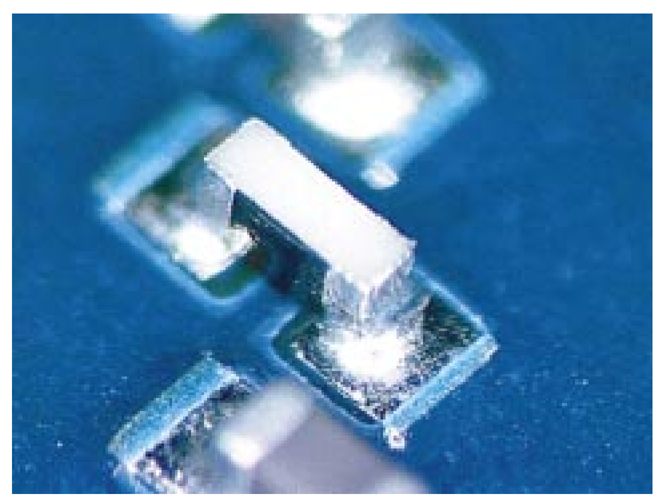


Figure 8-34

Acceptable - Class 1,2,3

- Width (W) to height (H) ratio does not exceed two to one (2:1) ratio; see Figure 8-33.
- Complete wetting at land to end cap metallization.
- Overlap contact between 100% of the component termination (metallization) and the land.
- Component has three or more termination faces (metallization).
- There is evidence of wetting on the three vertical faces of the termination area.

Acceptable - Class 1,2

- Component size may be larger than 1206.

8.2.2.9.1 Chip Components – Termination Variations – Mounting on Side (Billboarding) (cont.)

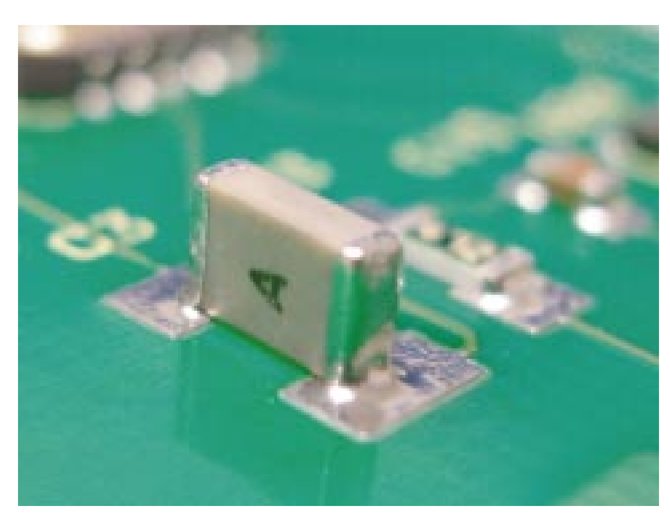


Figure 8-35

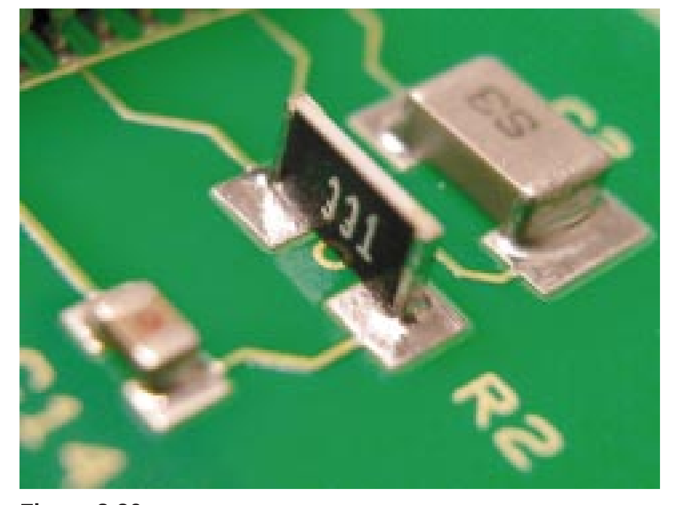


Figure 8-36

Defect - Class 1,2,3

- Width to height ratio exceeds two to one (2:1) ratio.
- Incomplete wetting at land or end cap metallization.
- Less than 100% overlap of the component termination (metallization) and the land.
- Component overhangs the end or side of the land.
- Component has less than three termination faces (metallization).

Defect - Class 3

- Component size is larger than 1206.

8.2.2.9.2 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Termination Variations – Mounting Upside Down

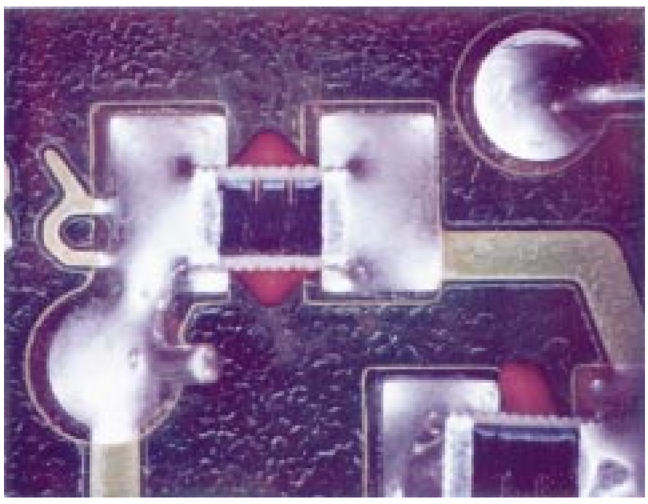


Figure 8-37

Target - Class 1,2,3

- Element of chip component with exposed deposited electrical element is mounted away from the board.

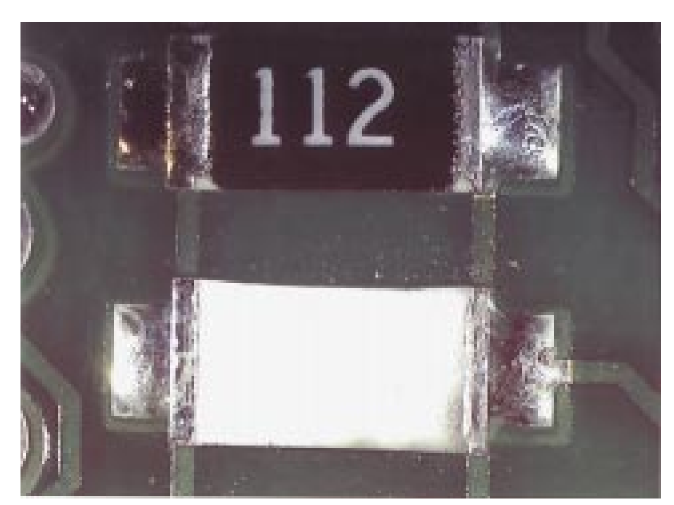


Figure 8-38

Acceptable - Class 1
Process Indicator - Class 2,3

- Element of chip component with exposed deposited electrical element is mounted toward the board.

8.2.2.9.3 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Termination Variations - Stacking

These criteria are applicable when stacking is a requirement.

When stacking components, the top termination area of a component becomes the land for the next higher component.

Stacking order of mixed component types, e.g., capacitors, resistors, needs to be established by design.

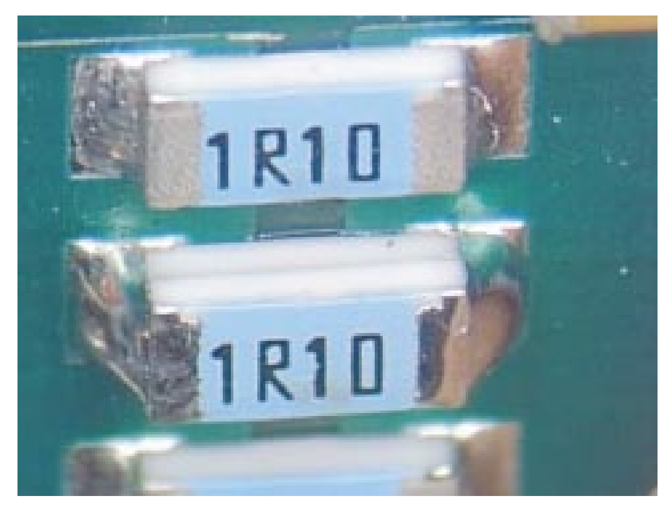


Figure 8-39

Acceptable - Class 1,2,3

- When permitted by drawing.
- All components meet the criteria of Table 8-2, features B through W for the applicable class of acceptance.
- Side overhang does not preclude formation of required solder fillets.

Defect - Class 1,2,3

- Stacked parts when not required by drawing.
- All components do not meet the criteria of Table 8-2, features B through W, for the applicable class of acceptance.
- Side overhang precludes formation of required solder fillets.

8.2.2.9.4 Chip Components – Rectangular or Square End Components – 1, 3 or 5 Side Termination, Termination Variations – Tombstoning

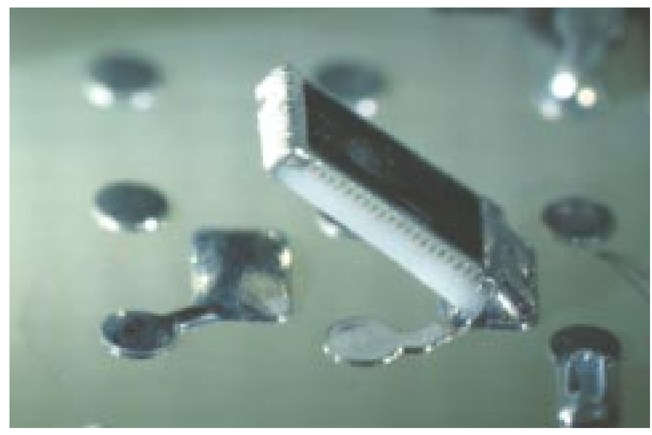


Figure 8-40

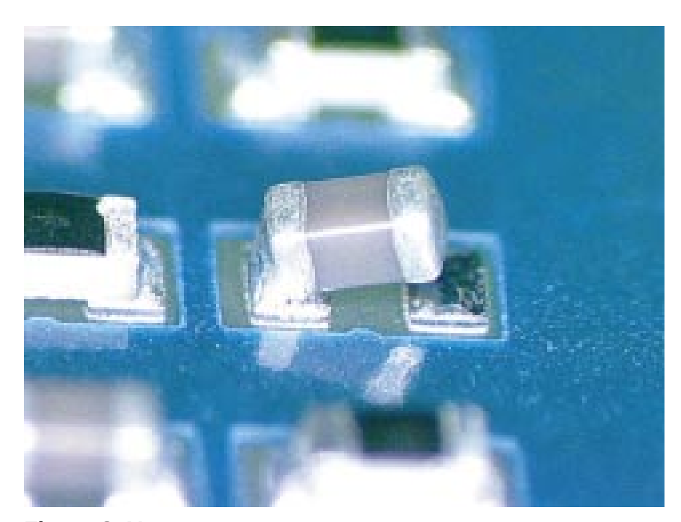


Figure 8-41

Defect - Class 1,2,3

- Chip components standing on a terminal end (tombstoning).

8.2.3 Cylindrical End Cap (MELF) Termination

Solder connections to components having cylindrical end cap terminations must meet the dimensional and solder fillet requirements for each product classification.

Table 8-3 Dimensional Criteria - Cylindrical End Cap (MELF) Termination

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	25% (W) or 25% (P), whichever is less; Note 1		
End Overhang	B	Not permitted		
Minimum End Joint Width, Note 2	C	Note 4	50% (W) or 50% (P), whichever is less	
Minimum Side Joint Length	D	Notes 4, 6	50% (R) or 50% (S), whichever is less; Note 6	75% (R) or 75% (S), whichever is less; Note 6
Maximum Fillet Height	E	Note 5		
Minimum Fillet Height (end and side)	F	Wetting is evident on the vertical surface(s) of the component termination. Note 7		(G) + 25% (W) or (G) + 1.0 mm [0.0394 in], whichever is less; Note 7
Solder Thickness	G	Note 4		
Minimum End Overlap	J	Notes 4, 6	50% (R) Note 6	75% (R) Note 6
Land Width	P	Note 3		
Termination/Plating Length	R	Note 3		
Land Length	S	Note 3		
Termination Diameter	W	Note 3		

Note 1. Does not violate minimum electrical clearance.
Note 2. (C) is measured from the narrowest side of the solder fillet.
Note 3. Unspecified dimension, determined by design.
Note 4. Wetting is evident.
Note 5. The maximum fillet may overhang the land or extend onto the top of the component termination; however, the solder does not extend further onto the component body.
Note 6. Does not apply to components with end-only terminations.
Note 7. Designs with via in pad may preclude meeting these criteria. Solder acceptance criteria should be defined between the user and the manufacturer.

8.2.3.1 Cylindrical End Cap Termination, Side Overhang (A)

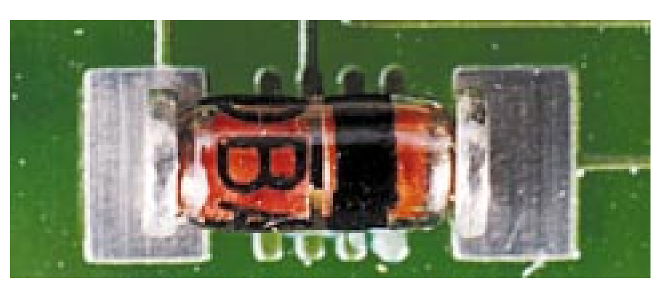


Figure 8-42

Target - Class 1,2,3

• No side overhang.

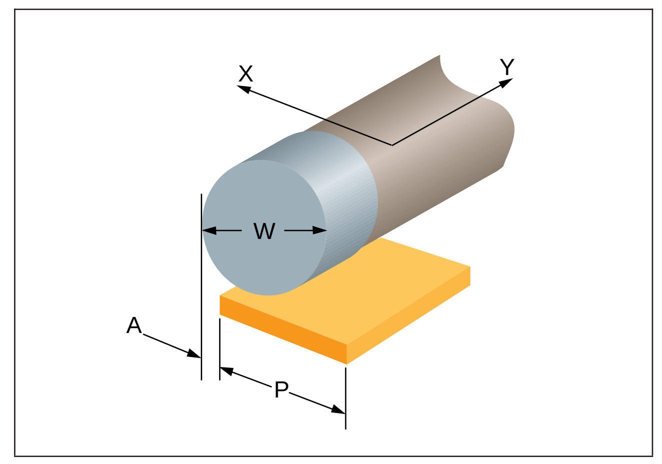


Figure 8-43

Acceptable - Class 1,2,3

• Side overhang (A) is 25% or less of the diameter of component width (W) or land width (P), whichever is less.

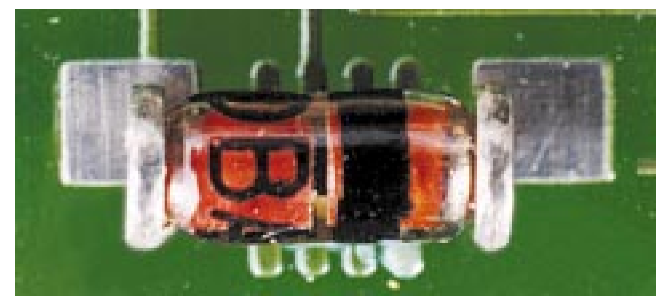


Figure 8-44

Defect - Class 1,2,3

• Side overhang (A) is greater than 25% of component diameter, (W), or land width (P), whichever is less.

8.2.3.2 Cylindrical End Cap Termination, End Overhang (B)

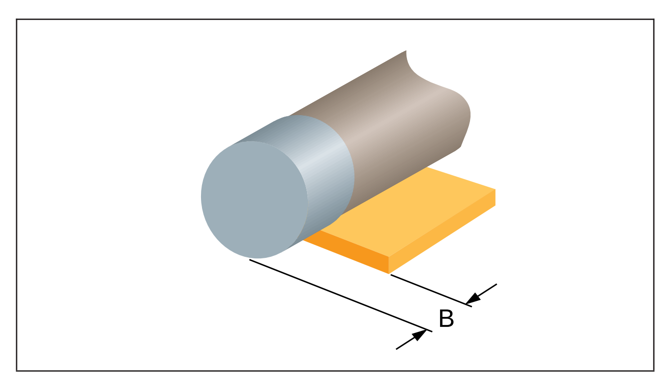


Figure 8-45

Target - Class 1,2,3

• No end overhang (B).

Defect - Class 1,2,3

• Any end overhang (B).

8.2.3.3 Cylindrical End Cap Termination, End Joint Width (C)

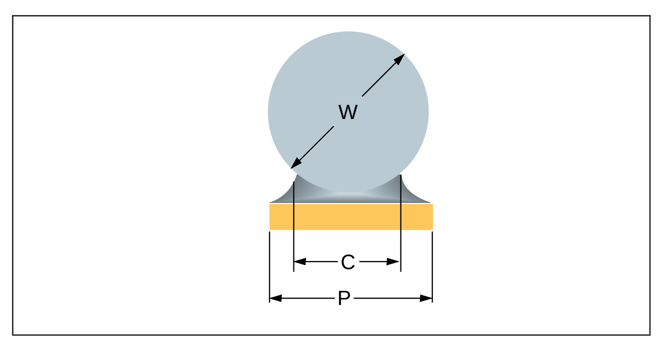


Figure 8-46

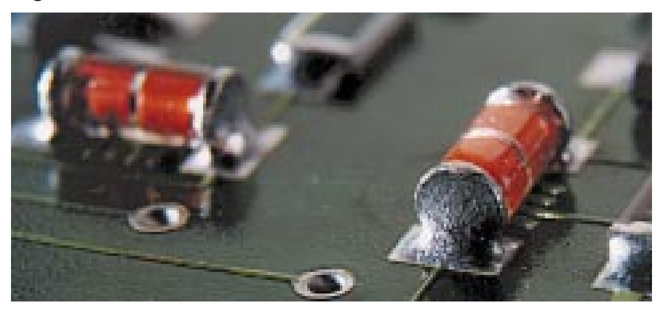


Figure 8-47



Figure 8-48

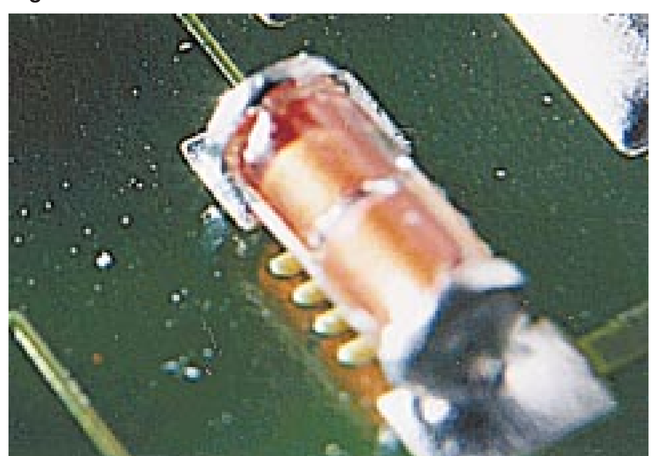


Figure 8-49

Target - Class 1,2,3

- End joint width is equal to or greater than the component diameter (W) or width of the land (P), whichever is less.

Acceptable - Class 1

- End solder joint exhibits a wetted fillet.

Acceptable - Class 2,3

- End joint width (C) is minimum 50% component diameter (W) or land width (P), whichever is less.

Defect - Class 1

- End solder joint does not exhibit a wetted fillet.

Defect - Class 2,3

- End joint width (C) is less than 50% component diameter (W), or land width (P), whichever is less.

8.2.3.4 Cylindrical End Cap Termination, Side Joint Length (D)

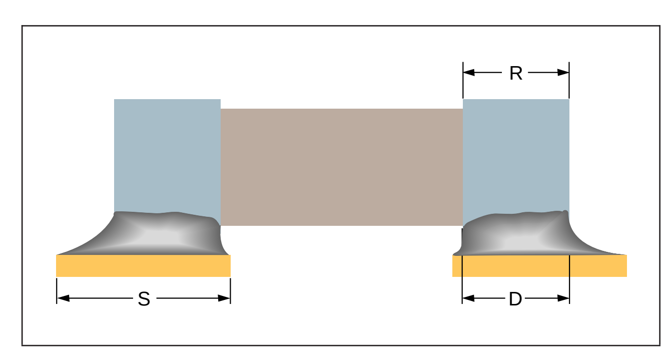


Figure 8-50



Figure 8-51

Target - Class 1,2,3

- Side joint length (D) is equal to the length of component termination (R) or land length (S) whichever is less.

Acceptable - Class 1

- Side joint length (D) exhibits a wetted fillet.

Acceptable - Class 2

- Side joint length (D) is minimum 50% length of component termination (R) or land length (S) whichever is less.

Acceptable - Class 3

- Side joint length (D) is minimum 75% length of component termination (R) or land length (S) whichever is less.

Defect - Class 1

- Side joint length (D) does not exhibit a wetted fillet.

Defect - Class 2

- Side joint length (D) is less than 50% length of component termination (R) or land length (S) whichever is less.

Defect - Class 3

- Side joint length (D) is less than 75% length of component termination (R) or land length (S) whichever is less.

8.2.3.5 Cylindrical End Cap Termination, Maximum Fillet Height (E)

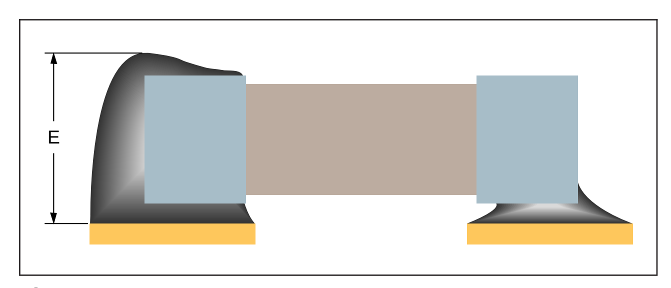


Figure 8-52

Acceptable - Class 1,2,3

- Maximum fillet height (E) may overhang the land and/or extend onto the top of the end cap metallization, but not extend further onto the component body.

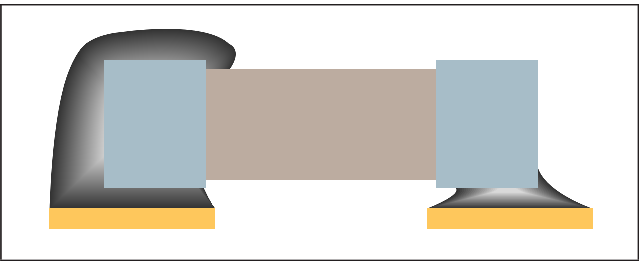


Figure 8-53

Defect - Class 1,2,3

- Solder fillet extends onto the component body top.

8.2.3.6 Cylindrical End Cap Termination, Minimum Fillet Height (F)

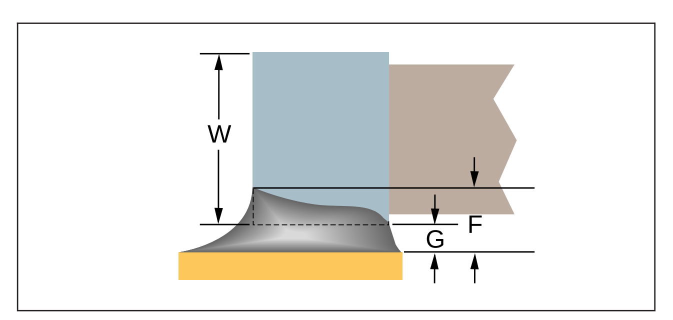


Figure 8-54

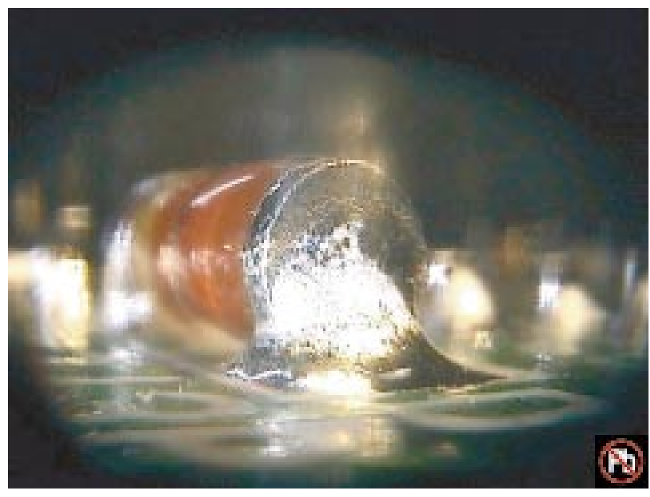


Figure 8-55

Acceptable - Class 1,2

- Minimum fillet height (F) exhibits wetting.

Acceptable - Class 3

- Minimum fillet height (F) is solder thickness (G) plus 25% diameter (W) of the component end cap or 1.0 mm [0.039 in], whichever is less.

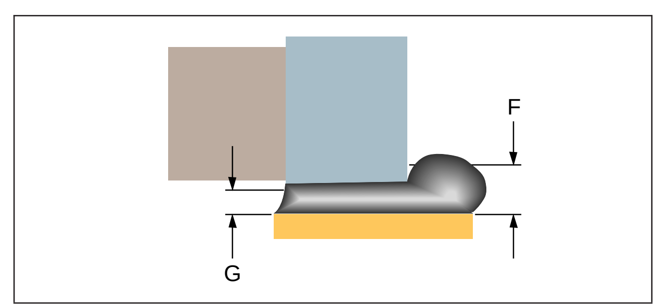


Figure 8-56

Defect - Class 1,2,3

- Minimum fillet height (F) does not exhibit wetting.

Defect - Class 3

- Minimum fillet height (F) is less than the solder thickness (G) plus 25% diameter (W) of the component end cap or 1.0 mm [0.039 in], whichever is less.

8.2.3.7 Cylindrical End Cap Termination, Solder Thickness (G)

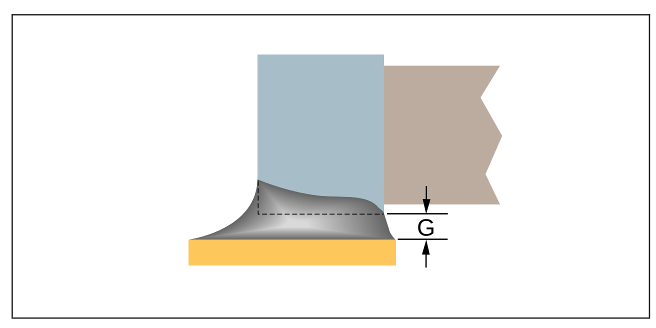


Figure 8-57

Acceptable - Class 1,2,3

- Wetted fillet evident.

Defect - Class 1,2,3

- No wetted fillet.

8.2.3.8 Cylindrical End Cap Termination, End Overlap (J)

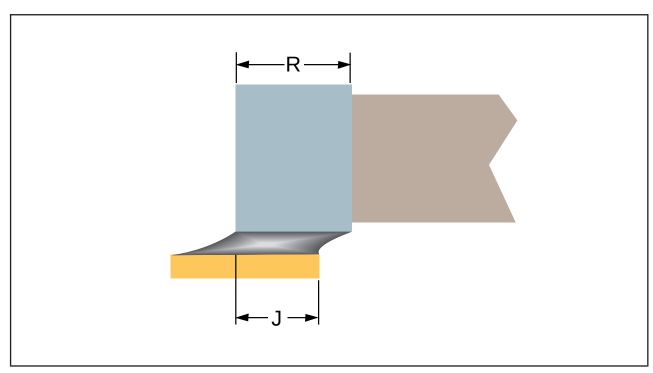


Figure 8-58

Acceptable - Class 1

- Wetted fillet is evident.

Acceptable - Class 2

- End overlap (J) between the component termination and the land is minimum 50% the length of component termination (R).

Acceptable - Class 3

- End overlap (J) between the component termination and the land is minimum of 75% the length of component termination (R).

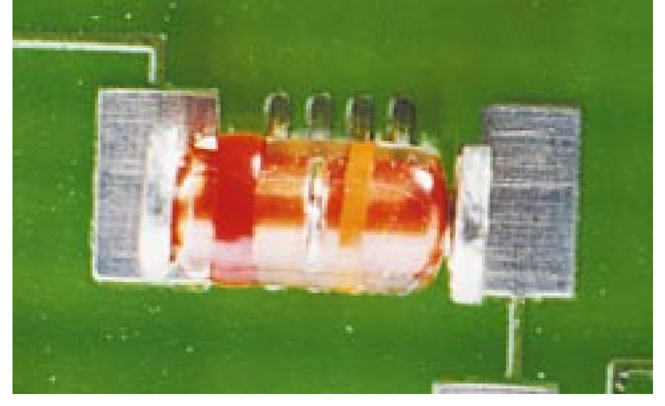


Figure 8-59

Defect - Class 1,2,3

- Component termination area and land do not overlap.

Defect - Class 2

- End overlap (J) is less than 50% of the length of component termination.

Defect - Class 3

- End overlap (J) is less than 75% of the length of component termination.

8.2.4 Castellated Terminations

Connections formed to castellated terminations of leadless chip components must meet the dimensional and solder fillet requirements listed below for each product classification. The solder fillet may contact the bottom of the component.

Table 8-4 Dimensional Criteria - Castellated Terminations

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) Note 1		25% (W) Note 1
End Overhang	B	Not permitted		
Minimum End Joint Width	C	50% (W)		75% (W)
Minimum Side Joint Length	D	Note 3	Depth of castellation	
Maximum Fillet Height	E	G + H		
Minimum Fillet Height	F	Note 3	(G) + 25% (H)	(G) + 50% (H)
Solder Thickness	G	Note 3		
Castellation Height	H	Note 2		
Land Length	S	Note 2		
Castellation Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, determined by design.
Note 3. Wetting is evident.

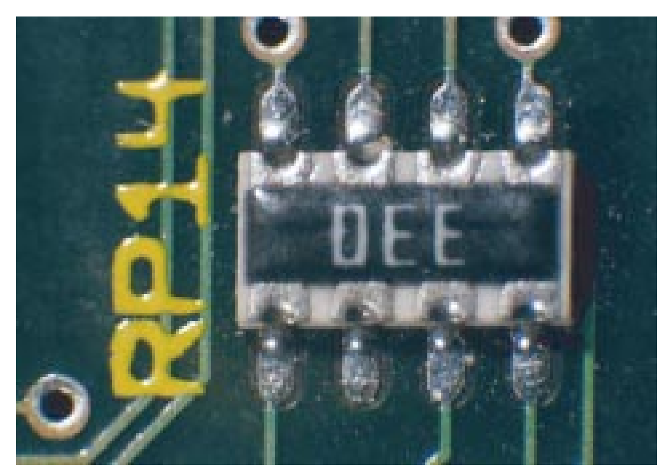


Figure 8-60

8.2.4.1 Castellated Terminations, Side Overhang (A)

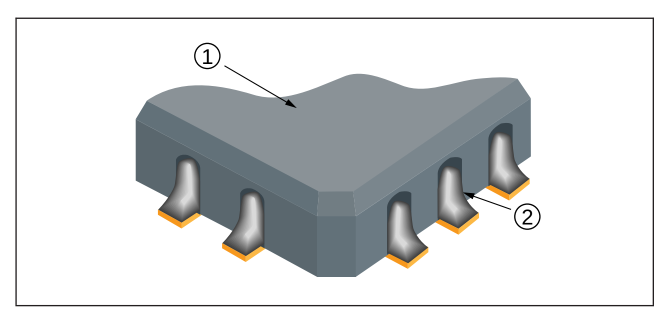


Figure 8-61

1. Leadless chip carrier
2. Castellations (Terminations)

Target - Class 1,2,3

- No side overhang.

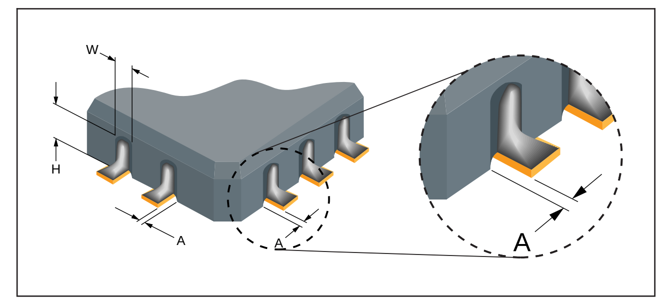


Figure 8-62

Acceptable - Class 1,2

- Maximum side overhang (A) is 50% castellation width (W).

Acceptable - Class 3

- Maximum side overhang (A) is 25% castellation width (W).

Defect - Class 1,2

- Side overhang (A) exceeds 50% castellation width (W).

Defect - Class 3

- Side overhang (A) exceeds 25% castellation width (W).

8.2.4.2 Castellated Terminations, End Overhang (B)

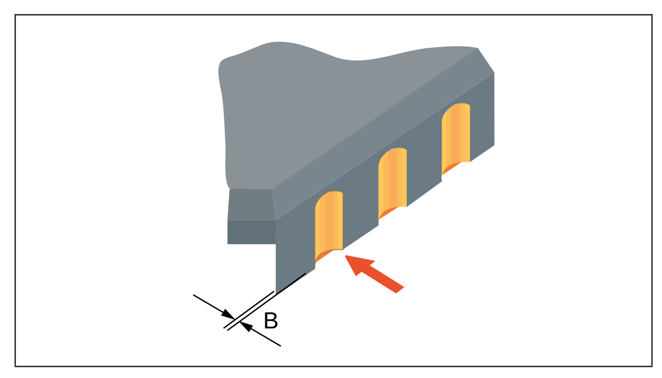


Figure 8-63

Acceptable - Class 1,2,3

• No end overhang.

Defect - Class 1,2,3

• End overhang (B).

8.2.4.3 Castellated Terminations, Minimum End Joint Width (C)

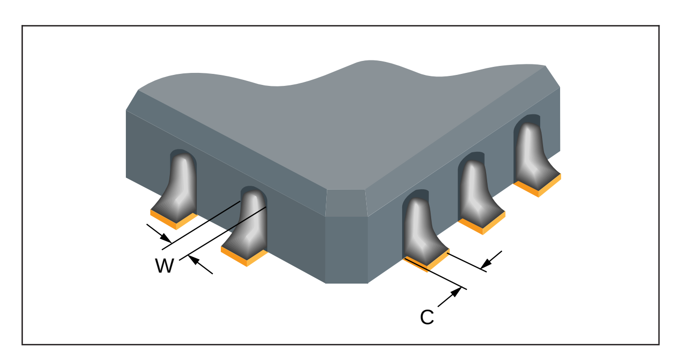


Figure 8-64

Target - Class 1,2,3

• End joint width (C) is equal to castellation width (W).

Acceptable - Class 1,2

• Minimum end joint width (C) is 50% castellation width (W).

Acceptable - Class 3

• Minimum end joint width (C) is 75% castellation width (W).

Defect - Class 1,2

• End joint width (C) is less than 50% castellation width (W).

Defect - Class 3

• End joint width (C) is less than 75% castellation width (W).

8.2.4.4 Castellated Terminations, Minimum Side Joint Length (D)

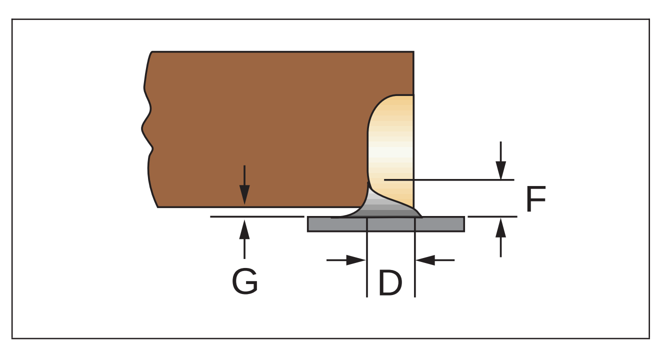


Figure 8-65

Acceptable - Class 1,2,3

- Solder extends from the back of the castellation onto the land at or beyond the edge of the component.

Defect - Class 1,2,3

- Solder does not extend from the back of the castellation onto the land at or beyond the edge of the component.

8.2.4.5 Castellated Terminations, Maximum Fillet Height (E)

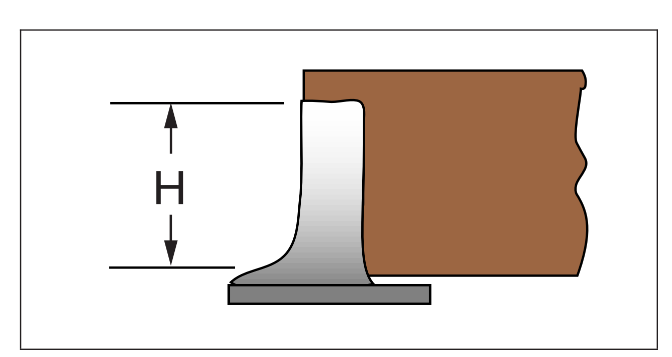


Figure 8-66

Acceptable - Class 1,2,3

- The fillet extends to the top of the castellation.

Note: There is no maximum fillet height defect.

8.2.4.6 Leadless Chip Carriers with Castellated Terminations, Minimum Fillet Height (F)

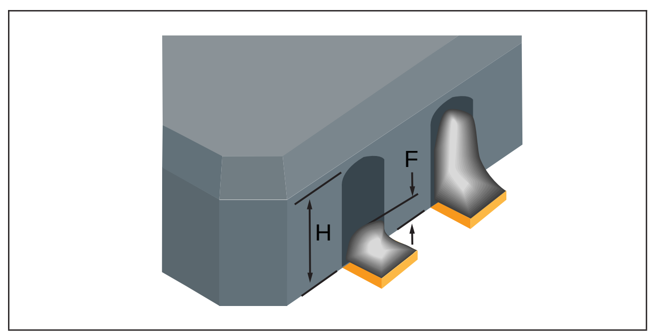


Figure 8-67

Acceptable - Class 1

- A wetted fillet is evident.

Acceptable - Class 2

- Minimum fillet height (F) is the solder thickness (G) (not shown) plus 25% castellation height (H).

Acceptable - Class 3

- Minimum fillet height (F) is the solder thickness (G) (not shown) plus 50% castellation height (H).

Defect - Class 1

- A wetted fillet is not evident.

Defect - Class 2

- Minimum fillet height (F) is less than solder thickness (G) (not shown) plus 25% castellation height (H).

Defect - Class 3

- Minimum fillet height (F) is less than solder thickness (G) (not shown) plus 50% castellation height (H).

8.2.4.7 Castellated Terminations, Solder Thickness (G)

Acceptable - Class 1,2,3

- Wetted fillet evident.

Defect - Class 1,2,3

- No wetted fillet.

8.2.5 Flat Ribbon, L, and Gull Wing Leads

Table 8-5 Dimensional Criteria - Flat Ribbon, L, and Gull Wing Leads

Feature		Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang		A	50% (W) or 0.5 mm [0.02 in], whichever is less; Note 1		25% (W) or 0.5 mm [0.02 in], whichever is less; Note 1
Maximum Toe Overhang		B	Note 1		
Minimum End Joint Width		C	50% (W)		75% (W)
Minimum Side Joint Length Note 6	when (L) is ≥3 W	D	(1W) or 0.5 mm [0.02 in], whichever is less	3 (W) or 75% (L), whichever is longer	
	when (L) is <3 W			100% (L)	
Maximum Heel Fillet Height		E	Note 4		
Minimum Heel Fillet Height		F	Note 3	(G) + 50% (T) Note 5	(G) + (T) Note 5
Solder Thickness		G	Note 3		
Formed Foot Length		L	Note 2		
Lead Thickness		T	Note 2		
Lead Width		W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, determined by design.
Note 3. Wetting is evident.
Note 4. See 8.2.5.5
Note 5. In the case of a toe-down lead configuration, the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.
Note 6. Fine pitch leads require a minimum side fillet length of 0.5 mm [0.02 in].

8.2.5.1 Flat Ribbon, L, and Gull Wing Leads, Side Overhang (A)

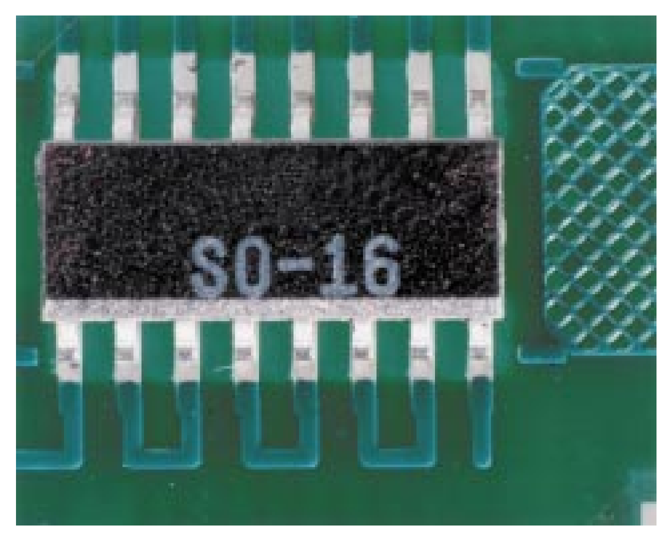


Figure 8-68

Target - Class 1,2,3

• No side overhang.

8.2.5.1 Flat Ribbon, L, and Gull Wing Leads, Side Overhang (A) (cont.)

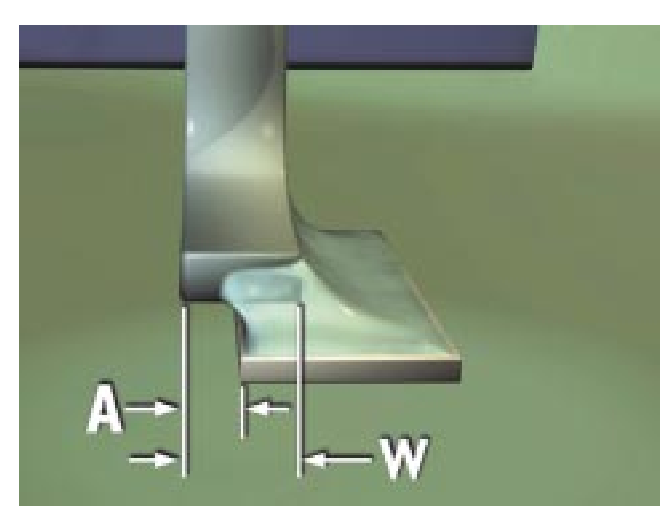


Figure 8-69

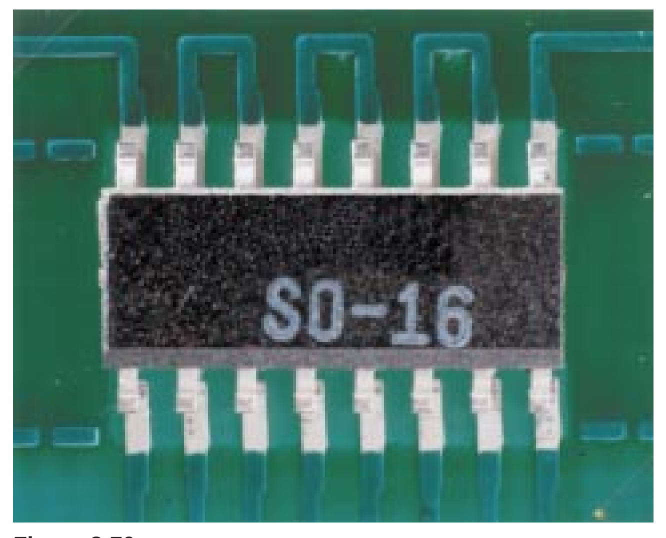


Figure 8-70

Acceptable - Class 1,2

- Maximum overhang (A) is not greater than 50% lead width (W) or 0.5 mm [0.02 in], whichever is less.

8.2.5.1 Flat Ribbon, L, and Gull Wing Leads, Side Overhang (A) (cont.)

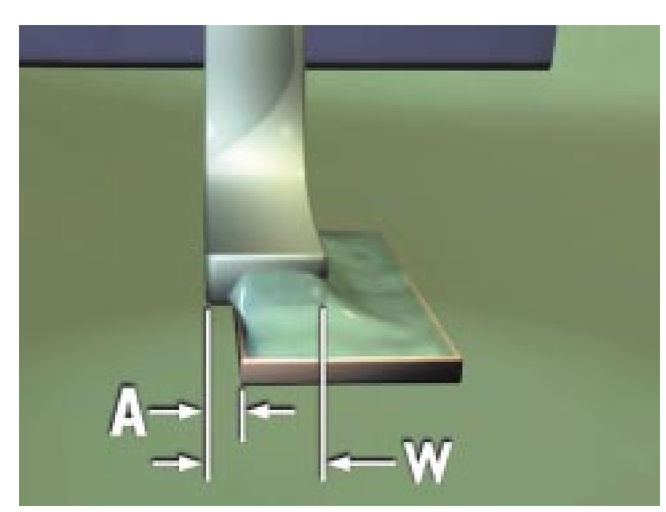


Figure 8-71

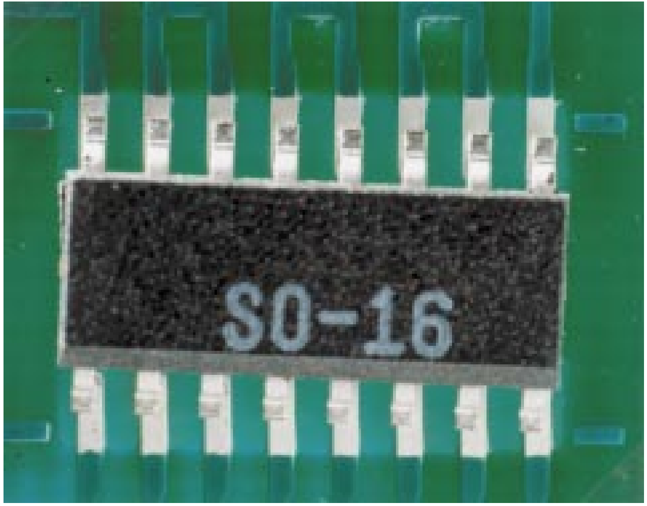


Figure 8-72

Acceptable - Class 3

- Maximum overhang (A) is not greater than 25% lead width (W) or 0.5 mm [0.02 in], whichever is less.

8.2.5.1 Flat Ribbon, L, and Gull Wing Leads, Side Overhang (A) (cont.)



Figure 8-73

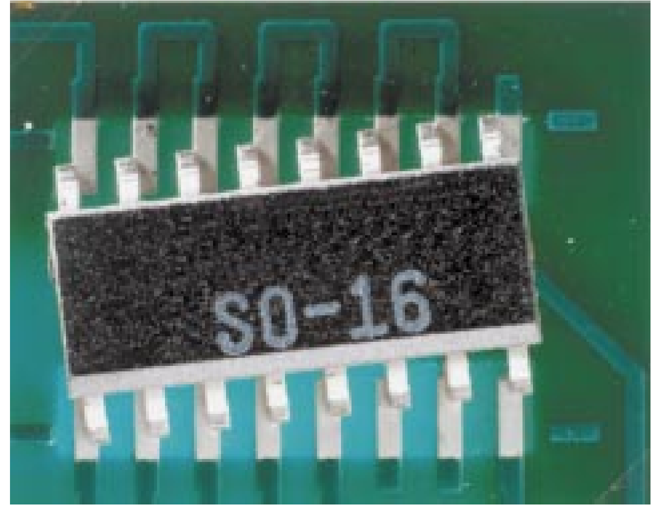


Figure 8-74

Defect - Class 1,2

- Side overhang (A) is greater than 50% lead width (W) or 0.5 mm [0.02 in], whichever is less.

Defect - Class 3

- Side overhang (A) is greater than 25% lead width (W) or 0.5 mm [0.02 in], whichever is less.

8.2.5.2 Flat Ribbon, L, and Gull Wing Leads, Toe Overhang (B)

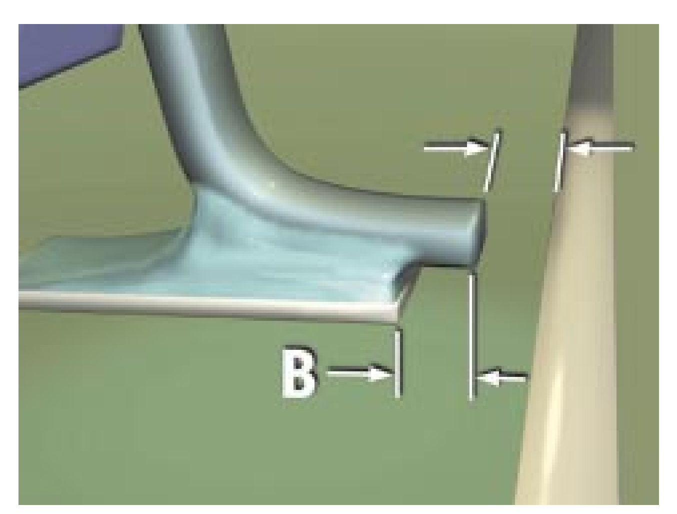


Figure 8-75

Acceptable - Class 1,2,3

- Toe overhang does not violate minimum electrical clearance.

Defect - Class 1,2,3

- Toe overhang violates minimum electrical clearance.

8.2.5.3 Flat Ribbon, L, and Gull Wing Leads, Minimum End Joint Width (C)



Figure 8-76

Target - Class 1,2,3

• End joint width is equal to or greater than lead width.

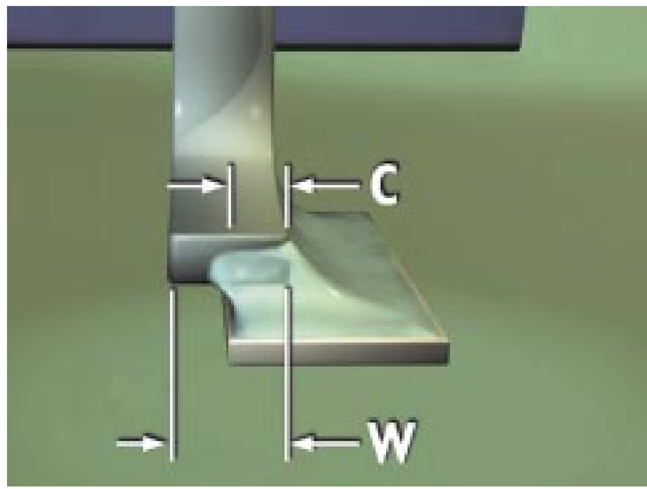


Figure 8-77

Acceptable - Class 1,2

• Minimum end joint width (C) is 50% lead width (W).

8.2.5.3 Flat Ribbon, L, and Gull Wing Leads, Minimum End Joint Width (C) (cont.)

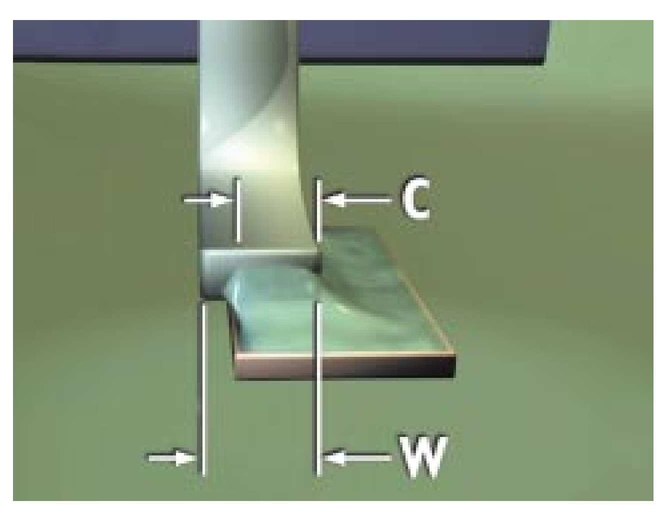


Figure 8-78

Acceptable - Class 3

• Minimum end joint width (C) is 75% lead width (W).

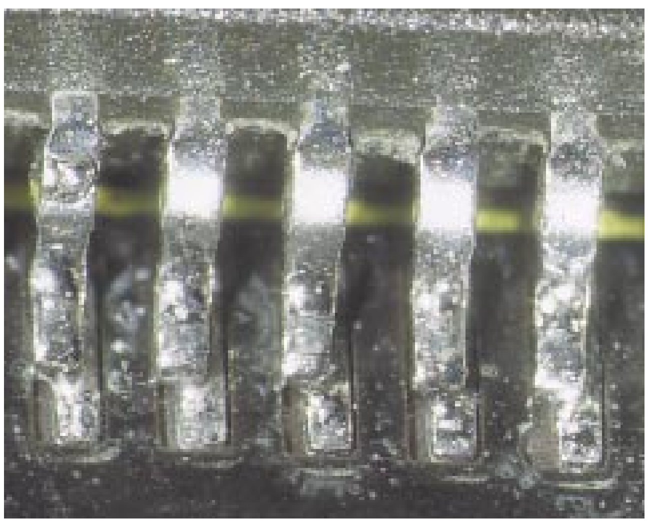


Figure 8-79

Defect - Class 1,2

• Minimum end joint width (C) is less than 50% lead width (W).

Defect - Class 3

• Minimum end joint width (C) is less than 75% lead width (W).

8.2.5.4 Flat Ribbon, L, and Gull Wing Leads, Minimum Side Joint Length (D)

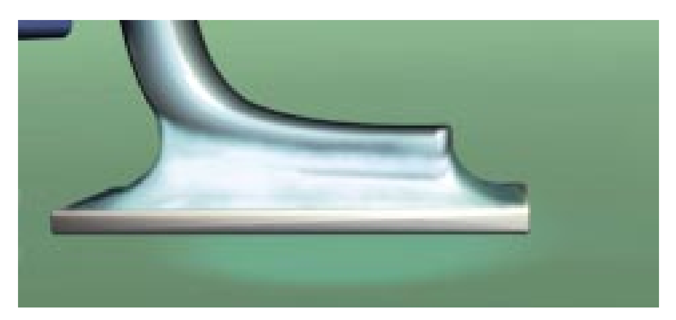


Figure 8-80

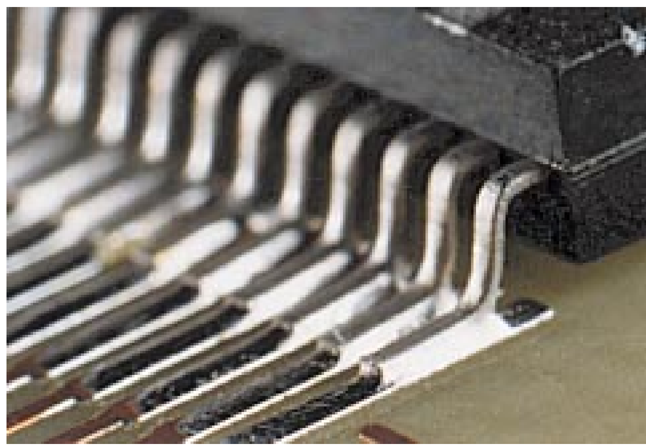


Figure 8-81



Figure 8-82

Target - Class 1,2,3

- Evidence of wetted fillet along full length of lead.

8.2.5.4 Flat Ribbon, L, and Gull Wing Leads, Minimum Side Joint Length (D) (cont.)

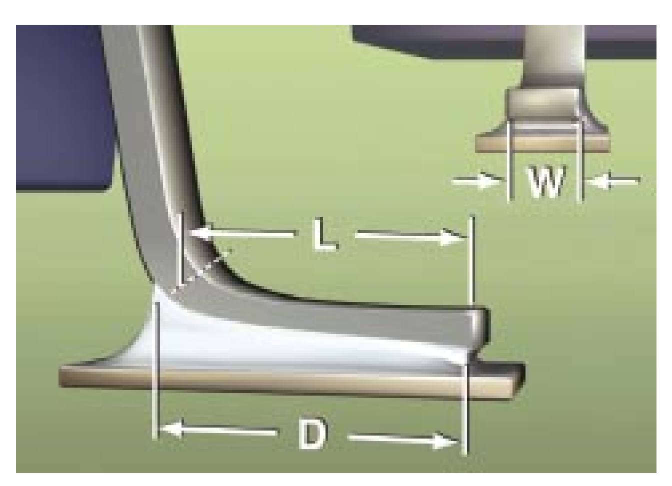


Figure 8-83

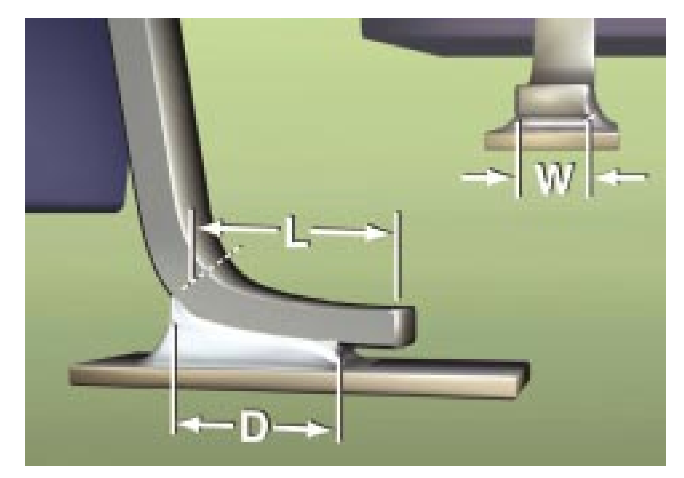


Figure 8-84

Acceptable - Class 1

- Minimum side joint length (D) is equal to lead width (W) or 0.5 mm [0.02 in], whichever is less (not shown).

Acceptable - Class 2,3

- When foot length (L) is greater than three (W), minimum side joint length (D) is equal to or greater than three lead widths (W) or 75% (L), whichever is longer, Figure 8-84.
- When foot length (L) is less than three (W), (D) is equal to 100% (L), Figure 8-83.

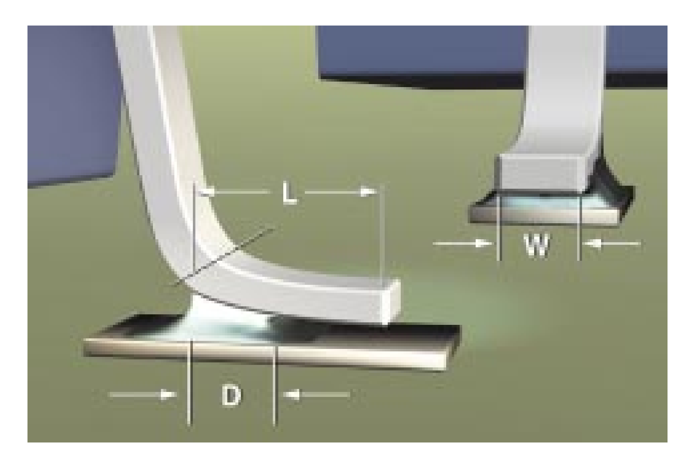


Figure 8-85

Defect - Class 1

- Minimum side joint length (D) is less than the lead width (W) or 0.5 mm [0.02 in], whichever is less.

Defect - Class 2,3

- When foot length (L) is greater than three (W), minimum side joint length (D) is less than three lead widths (W) or 75% (L), whichever is longer.
- When foot length (L) is less than three (W), (D) is less than 100% (L).

8.2.5.5 Flat Ribbon, L, and Gull Wing Leads, Maximum Heel Fillet Height (E)

In the following criteria, the words ''plastic component'' are used in the generic sense to differentiate between plastic components and those made of other materials, e.g., ceramic/alumina or metal (normally hermetically sealed).

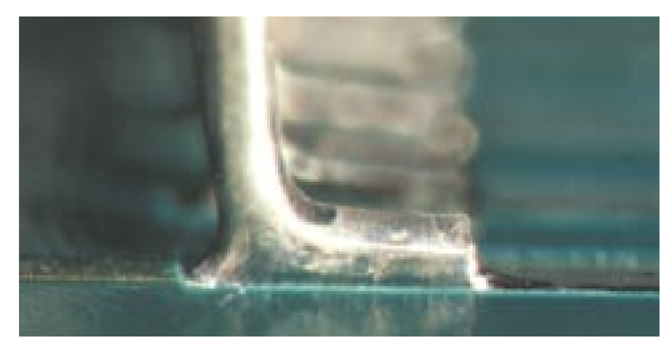


Figure 8-86

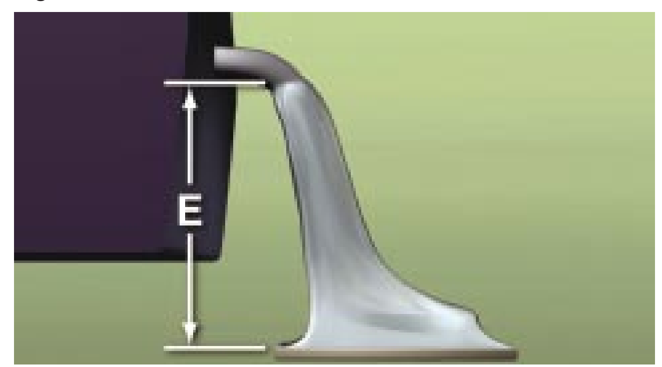


Figure 8-87

Target - Class 1,2,3

- Heel fillet extends above lead thickness but does not fill upper lead bend.
- Solder does not contact the component body.

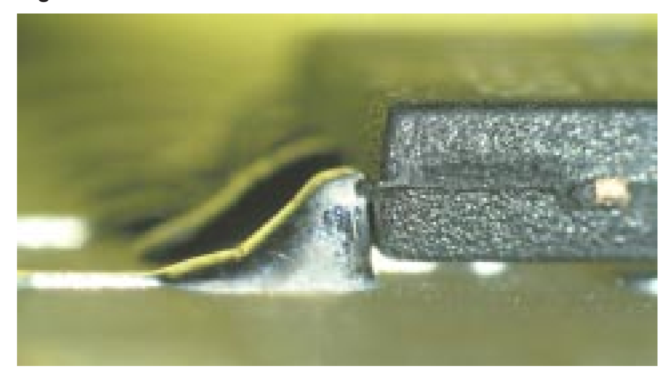


Figure 8-88

Acceptable - Class 1,2,3

- Solder touches a plastic SOIC or SOT component.
- Solder does not touch ceramic or metal component.

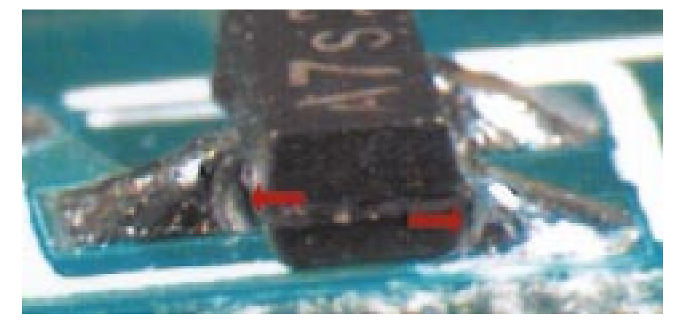


Figure 8-89

Acceptable - Class 1
Defect - Class 2,3

- Solder touches the body of a plastic component, except for SOICs and SOTs.
- Solder touches the body of a ceramic or metal component.

8.2.5.6 Flat Ribbon, L, and Gull Wing Leads, Minimum Heel Fillet Height (F)

Target - Class 1,2,3

- Heel fillet height (F) is greater than solder thickness (G) plus lead thickness (T) but does not extend into knee bend radius.

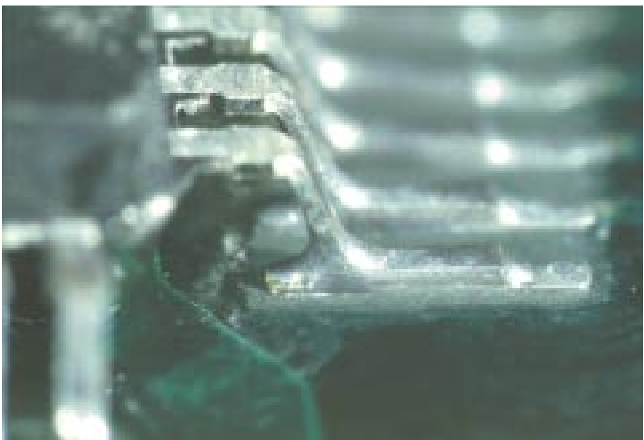


Figure 8-90

Acceptable - Class 1

- A wetted fillet is evident.

Figure 8-91

Acceptable - Class 2

- Minimum heel fillet height (F) is equal to solder thickness (G) plus 50% lead thickness (T) at connection side.

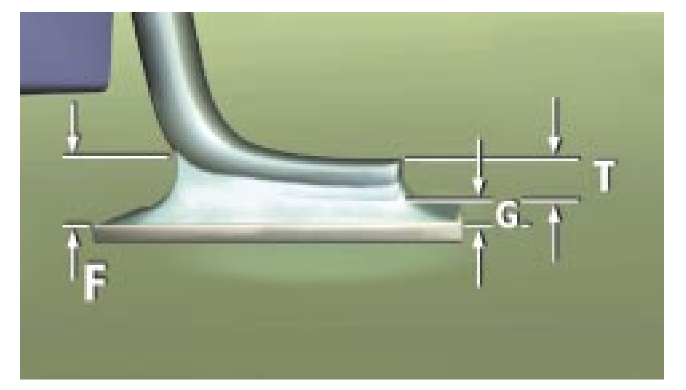


Figure 8-92

Acceptable - Class 3

- Minimum heel fillet height (F) is equal to solder thickness (G) plus lead thickness (T) at connection side.

Acceptable - Class 1,2,3

- In the case of a toe-down configuration (not shown), the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.

8.2.5.6 Flat Ribbon, L, and Gull Wing Leads, Minimum Heel Fillet Height (F) (cont.)



Figure 8-93

Defect - Class 1

- A wetted fillet is not evident.

Defect - Class 2

- Minimum heel fillet height (F) is less than solder thickness (G) plus 50% lead thickness (T) at connection side.

Defect - Class 3

- Minimum heel fillet height (F) is less than solder thickness (G) plus lead thickness (T) at connection side.

Defect - Class 1,2,3

- In the case of a toe-down configuration, the minimum heel fillet height (F) does not extend at least to the mid-point of the outside lead bend.

8.2.5.7 Flat Ribbon, L, and Gull Wing Leads, Solder Thickness (G)

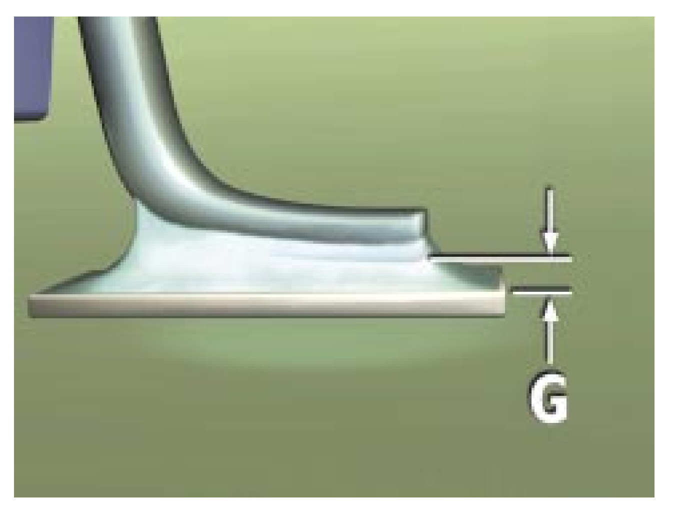


Figure 8-94

Acceptable - Class 1,2,3

- Wetted fillet evident.

Defect - Class 1,2,3

- No wetted fillet.

8.2.5.8 Flat Ribbon, L, and Gull Wing Leads, Coplanarity

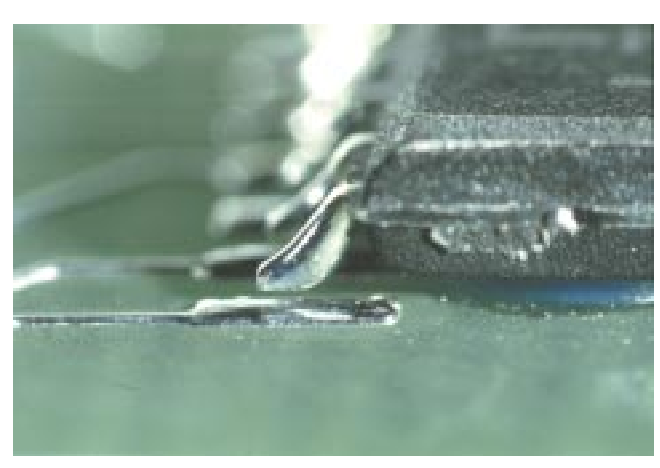


Figure 8-95

Defect - Class 1,2,3

- Component lead(s) out of alignment (coplanarity) preventing the formation of an acceptable solder joint.

8.2.6 Round or Flattened (Coined) Leads

Table 8-6 Dimensional Criteria - Round or Flattened (Coined) Lead Features

Feature	Dim	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) or 0.5 mm [0.02 in], whichever is less; Note 1		25% (W) or 0.5 mm [0.02 in], whichever is less; Note 1
Maximum Toe Overhang	B	Note 1		
Minimum End Joint Width	C	Note 3		75% (W)
Minimum Side Joint Length	D	100% (W)		150% (W)
Maximum Heel Fillet Height	E	Note 4		
Minimum Heel Fillet Height	F	Note 3	(G) + 50% (T) Note 5	(G) + (T) Note 5
Solder Thickness	G	Note 3		
Formed Foot Length	L	Note 2		
Minimum Side Joint Height	Q	Note 3	(G) + 50% (T)	
Thickness of Lead at Joint Side	T	Note 2		
Flattened Lead Width or Diameter of Round Lead	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, determined by design.
Note 3. Wetting is evident.
Note 4. See 8.2.6.5
Note 5. In the case of a toe-down lead configuration, the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.

8.2.6.1 Round or Flattened (Coined) Leads, Side Overhang (A)

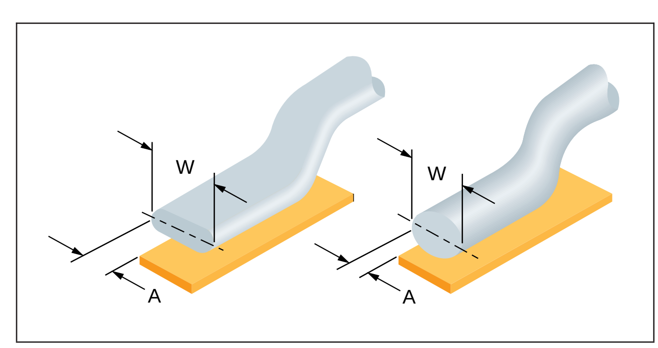


Figure 8-96

Target - Class 1,2,3

- No side overhang.

Acceptable - Class 1,2

- Side overhang (A) is not greater than 50% lead width/diameter (W).

Acceptable - Class 3

- Side overhang (A) is not greater than 25% lead width/diameter (W).

Defect - Class 1,2

- Side overhang (A) is greater than 50% lead width/diameter (W).

Defect - Class 3

- Side overhang (A) is greater than 25% lead width/diameter (W).

8.2.6.2 Round or Flattened (Coined) Leads, Toe Overhang (B)

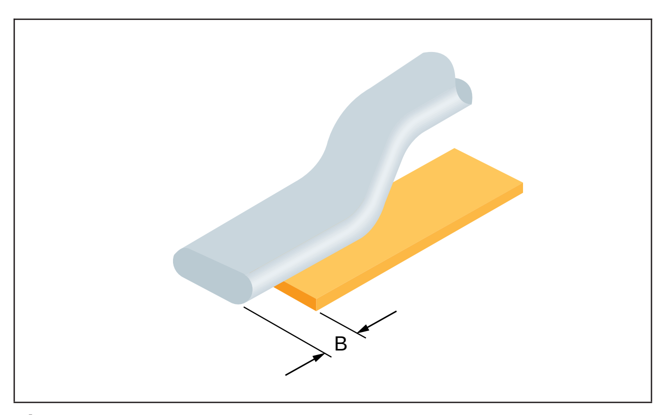


Figure 8-97

Acceptable - Class 1,2,3

- Toe overhang (B) is not specified.
- Does not violate minimum electrical clearance.

Defect - Class 1,2,3

- Toe overhang violates minimum electrical clearance.

8.2.6.3 Round or Flattened (Coined) Leads, Minimum End Joint Width (C)

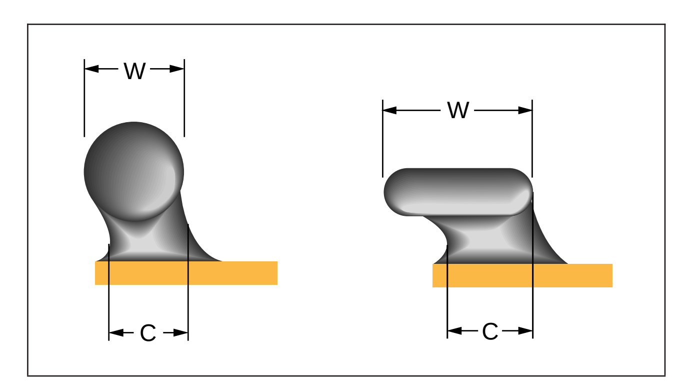


Figure 8-98

Target - Class 1,2,3

- End joint width (C) is equal to or greater than lead width/diameter (W).

Acceptable - Class 1,2

- Wetted fillet is evident.

Acceptable - Class 3

- End joint width (C) is minimum 75% lead width/diameter (W).

Defect - Class 1,2

- No evidence of wetted fillet.

Defect - Class 3

- Minimum end joint width (C) is less than 75% lead width/diameter (W).

8.2.6.4 Round or Flattened (Coined) Leads, Minimum Side Joint Length (D)

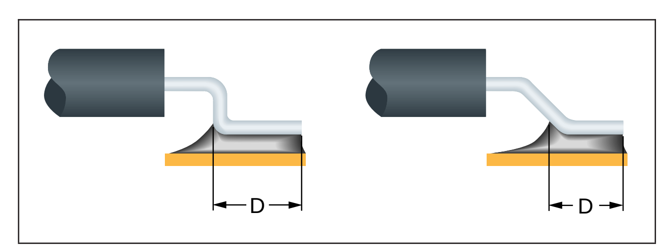


Figure 8-99

Acceptable - Class 1,2

• Side joint length (D) is equal to lead width/diameter (W).

Acceptable - Class 3

• Minimum side joint length (D) is equal to 150% lead width/diameter (W).

Defect - Class 1,2

• Side joint length (D) is less than lead width/diameter (W).

Defect - Class 3

• Minimum side joint length (D) is less than 150% the lead width/diameter (W).

8.2.6.5 Round or Flattened (Coined) Leads, Maximum Heel Fillet Height (E)

In the following criteria, the words ‘‘plastic component’’ are used in the generic sense to differentiate between plastic components and those made of other materials, e.g., ceramic/alumina or metal (normally hermetically sealed).

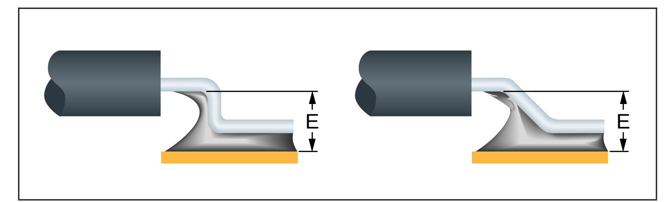


Figure 8-100

Target - Class 1,2,3

- Heel fillet extends above lead thickness but does not fill upper lead bend.
- Solder does not contact the component body.

Acceptable - Class 1,2,3

- Solder touches the body of a plastic SOIC or SOT component.
- Solder does not touch body of ceramic or metal component.

Defect - Class 1

- A wetted fillet is not evident.

Acceptable - Class 1
Defect - Class 2,3

- Solder touches the body of a plastic component, except for SOICs and SOTs.
- Solder touches the body of ceramic or metal component.

Defect - Class 1,2,3

- Solder is excessive so that the minimum electrical clearance is violated.

8.2.6.6 Round or Flattened (Coined) Leads, Minimum Heel Fillet Height (F)

Acceptable - Class 1,2,3

- In the case of a toe-down configuration (not shown), the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.

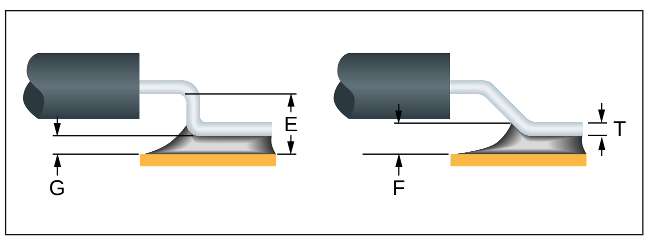


Figure 8-101

Acceptable - Class 1

- A wetted fillet is evident.

Acceptable - Class 2

- Minimum heel fillet height (F) is equal to solder thickness (G) plus 50% thickness of lead at joint side (T).

Acceptable - Class 3

- Minimum heel fillet height (F) is equal to solder thickness (G) plus thickness of lead at joint side (T).

Defect - Class 1

- A wetted fillet is not evident.

Defect - Class 2

- Minimum heel fillet height (F) is less than solder thickness (G) plus 50% thickness of lead at joint side (T).

Defect - Class 3

- Minimum heel fillet height (F) is less than solder thickness (G) plus thickness of lead at joint side (T).

Defect - Class 1,2,3

- In the case of a toe-down configuration, the minimum heel fillet height (F) does not extend at least to the mid-point of the outside lead bend.

8.2.6.7 Round or Flattened (Coined) Leads, Solder Thickness (G)

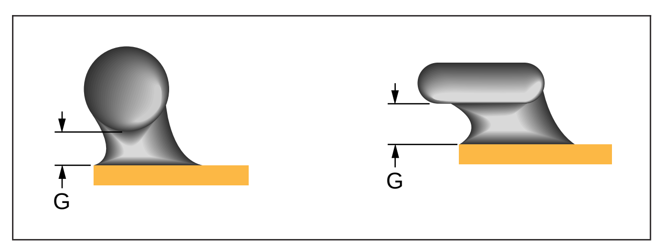


Figure 8-102

Acceptable - Class 1,2,3

• Wetted fillet evident.

Defect - Class 1,2,3

• No wetted fillet.

8.2.6.8 Round or Flattened (Coined) Leads, Minimum Side Joint Height (Q)

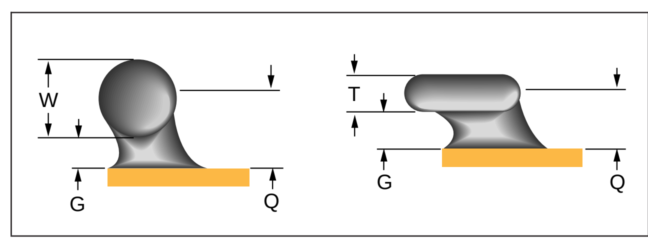


Figure 8-103

Acceptable - Class 1

• A wetted fillet is evident.

Acceptable - Class 2,3

• Minimum side joint height (Q) is equal to or greater than solder thickness (G) plus 50% diameter (W) of round lead or 50% thickness of lead at joint side (T) for coined lead.

Defect - Class 1

• A wetted fillet is not evident.

Defect - Class 2,3

• Minimum side joint height (Q) is less than solder thickness (G) plus 50% diameter (W) of round lead or 50% thickness of lead at joint side (T) for coined lead.

8.2.6.9 Round or Flattened (Coined) Leads, Coplanarity

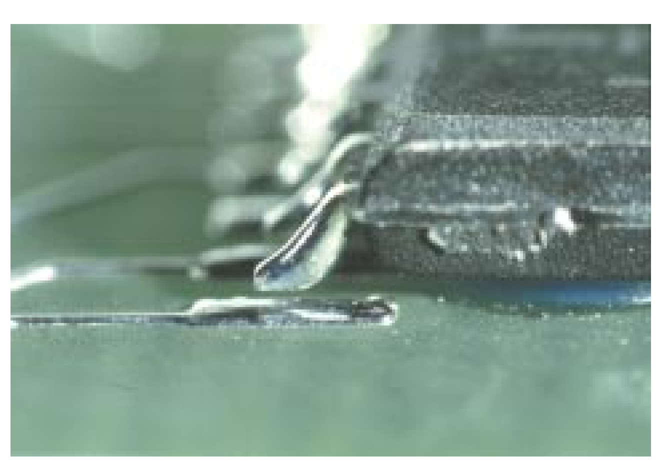


Figure 8-104

Defect - Class 1,2,3

- One lead or series of leads on component is out of alignment and fails to make contact with the land.

8.2.7 J Leads

Connections formed to leads having a J shape at the connection site must meet the dimensional and fillet requirements listed below for each product classification.

Table 8-7 Dimensional Criteria - "J" Leads

Feature	Dim.	Class I	Class 2	Class 3
Maximum Side Overhang	A	50% (W) Note 1		25% (W) Note 1
Maximum Toe Overhang	B	Notes 1, 2		
Minimum End Joint Width	C	50% (W)		75% (W)
Minimum Side Joint Length	D	Note 3	150% (W)	
Maximum Fillet Height	E	Note 4		
Minimum Heel Fillet Height	F	(G) + 50% (T)		(G) + (T)
Solder Thickness	G	Note 3		
Lead Thickness	T	Note 2		
Lead Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, determined by design.
Note 3. Wetting is evident.
Note 4. Solder does not touch package body.

8.2.7.1 J Leads, Side Overhang (A)

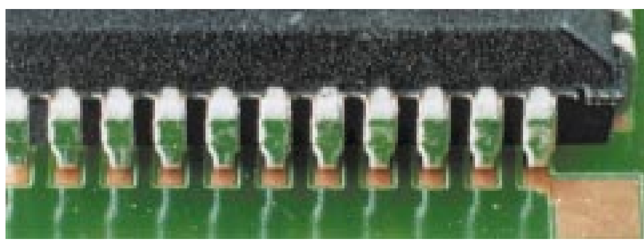


Figure 8-105

Target - Class 1,2,3

• No side overhang.

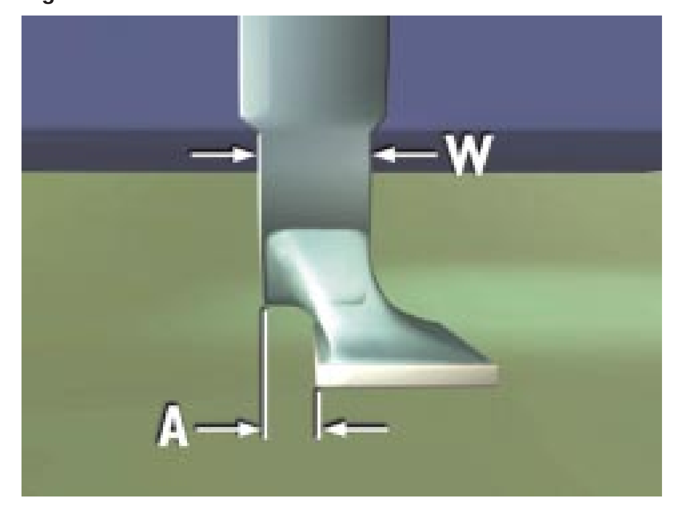
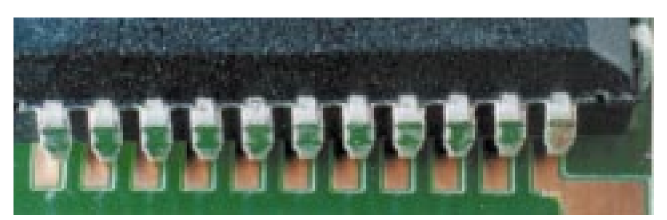


Figure 8-106

Acceptable - Class 1,2

• Side overhang (A) equal to or less than 50% lead width (W).

8.2.7.1 J Leads, Side Overhang (A) (cont.)


Figure 8-107

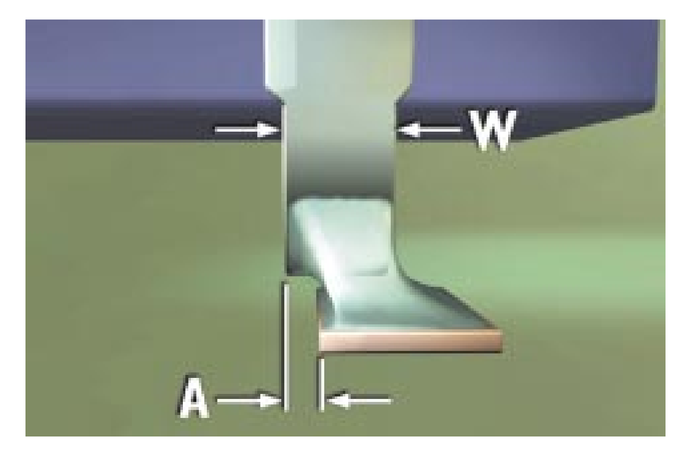
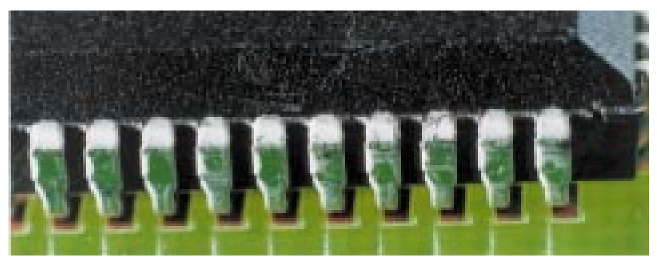
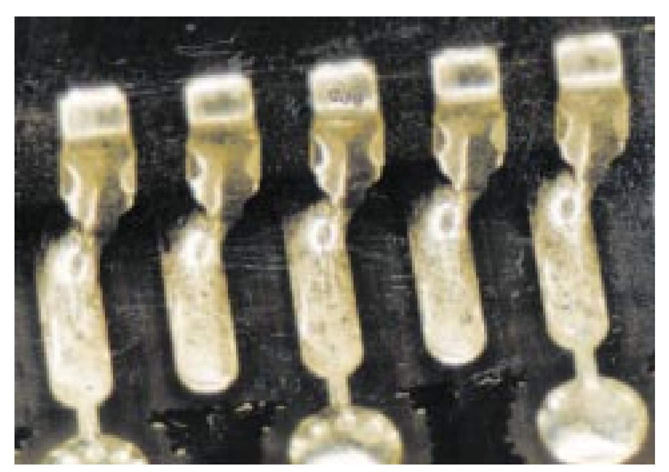


Figure 8-108

Acceptable - Class 3

• Side overhang (A) equal to or less than 25% lead width (W).


Figure 8-109


Figure 8-110

Defect - Class 1,2

• Side overhang exceeds 50% lead width (W).

Defect - Class 3

• Side overhang exceeds 25% lead width (W).

8.2.7.2 J Leads, Toe Overhang (B)

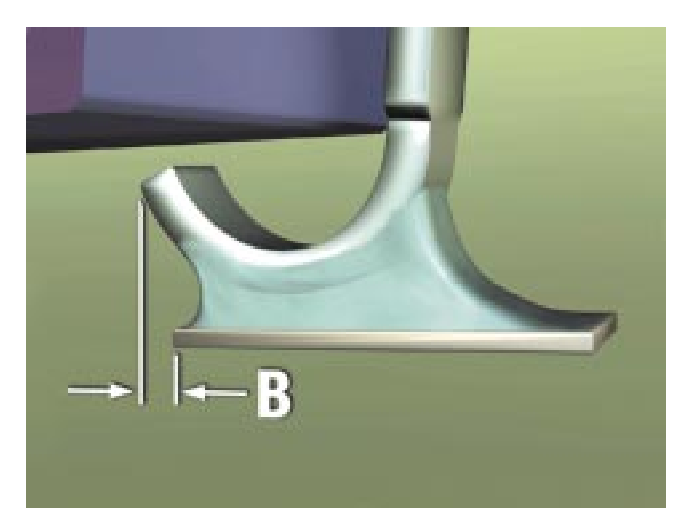


Figure 8-111

Acceptable - Class 1,2,3

- Toe overhang (B) is an unspecified parameter.

8.2.7.3 J Leads, End Joint Width (C)

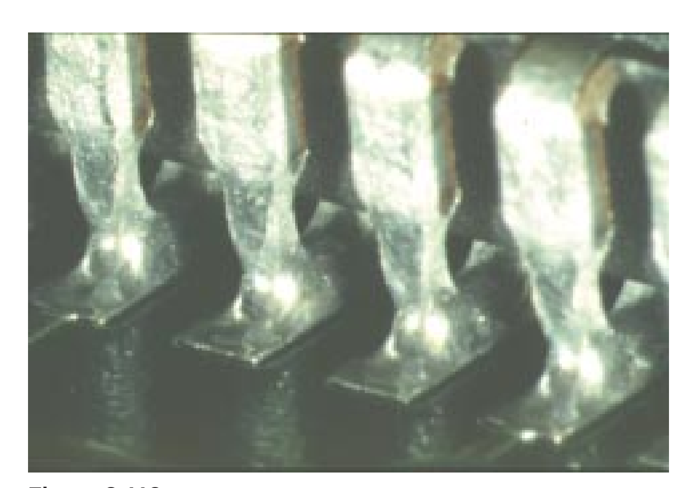


Figure 8-112

Target - Class 1,2,3

- End joint width (C) is equal to or greater than lead width (W).

8.2.7.3 J Leads, End Joint Width (C) (cont.)

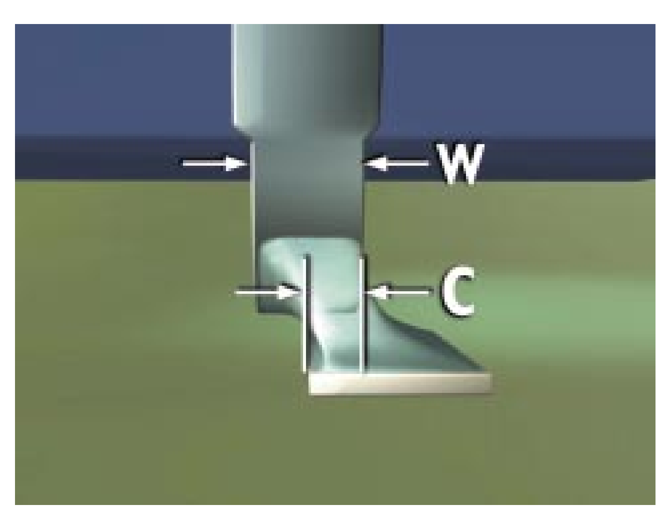


Figure 8-113

Acceptable - Class 1,2

- Minimum end joint width (C) is 50% lead width (W).

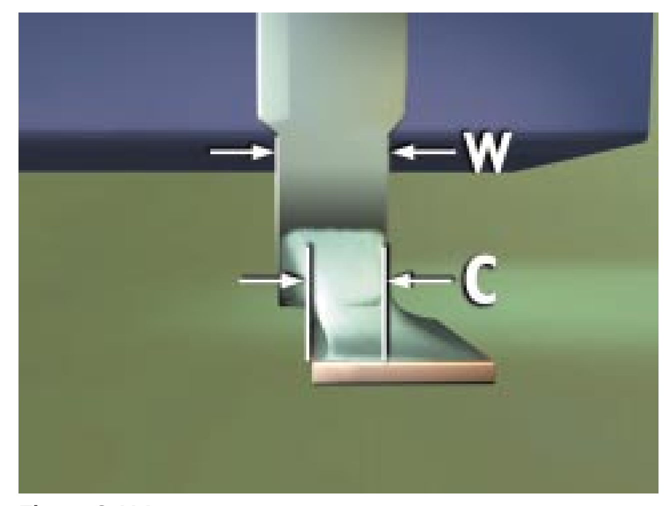


Figure 8-114

Acceptable - Class 3

- Minimum end joint width (C) is 75% lead width (W).

Defect - Class 1,2

- Minimum end joint width (C) is less than 50% lead width (W).

Defect - Class 3

- Minimum end joint width (C) is less than 75% lead width (W).

8.2.7.4 J Leads, Side Joint Length (D)



Figure 8-115

Target - Class 1,2,3

- Side joint length (D) is greater than 200% lead width (W).



Figure 8-116

Acceptable - Class 1

- Wetted fillet.

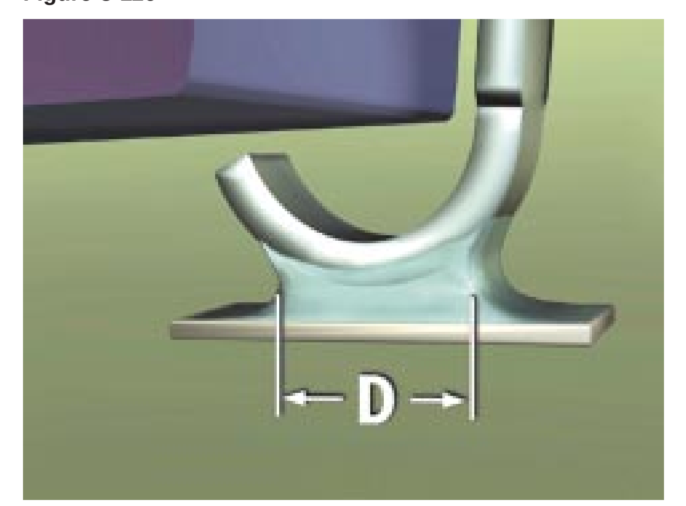


Figure 8-117

Acceptable - Class 2,3

- Side joint length (D) ≥150% lead width (W).

Defect - Class 2,3

- Side joint fillet (D) less than 150% lead width (W).

Defect - Class 1,2,3

- A wetted fillet is not evident.

8.2.7.5 J Leads, Maximum Fillet Height (E)

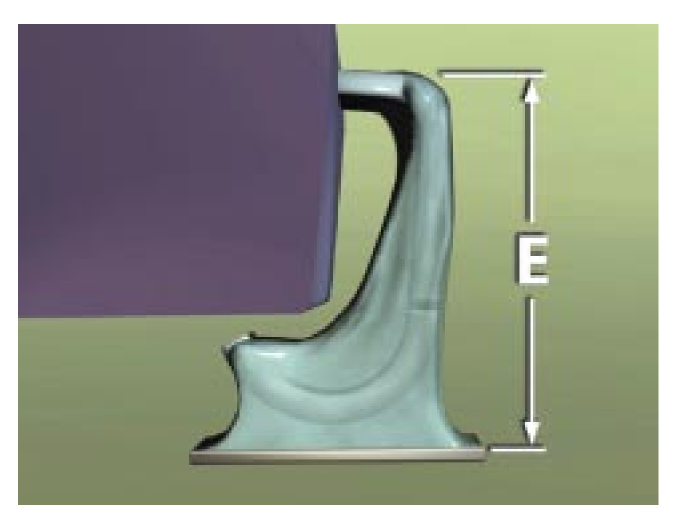


Figure 8-118

Acceptable - Class 1,2,3

- Solder fillet does not touch package body.

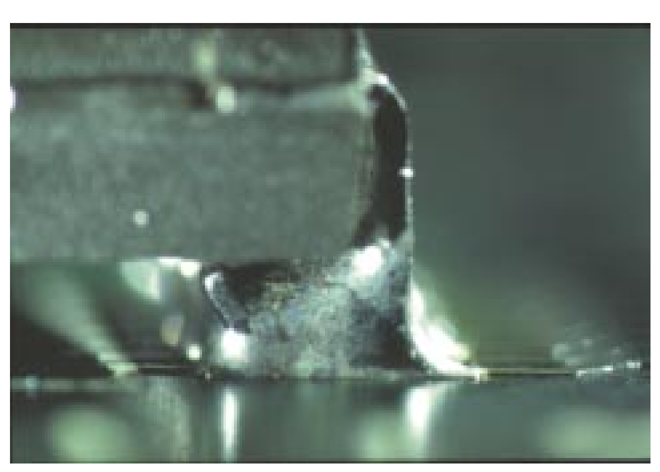


Figure 8-119

Defect - Class 1,2,3

- Solder fillet touches package body.

8.2.7.6 J Leads, Minimum Heel Fillet Height (F)

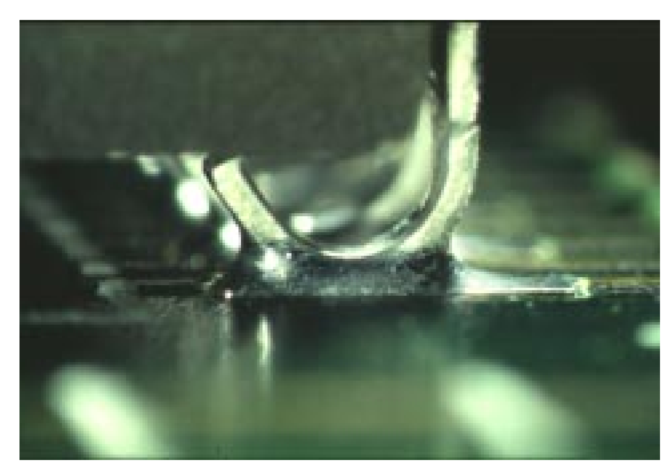


Figure 8-120

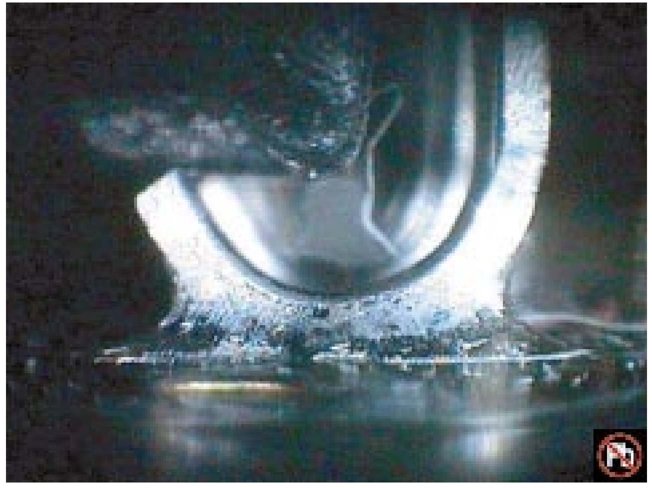


Figure 8-121

Target - Class 1,2,3

• Heel fillet height (F) exceeds lead thickness (T) plus solder thickness (G).

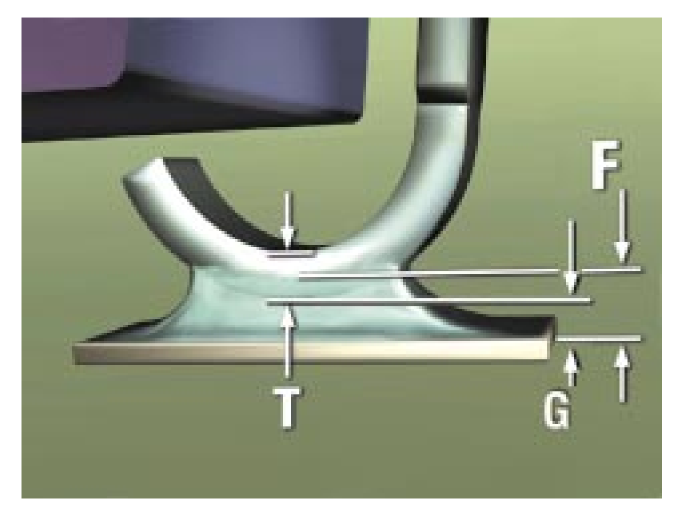


Figure 8-122

Acceptable - Class 1,2

• Heel fillet height (F) is minimum 50% lead thickness (T) plus solder thickness (G).

8.2.7.6 J Leads, Minimum Heel Fillet Height (F) (cont.)

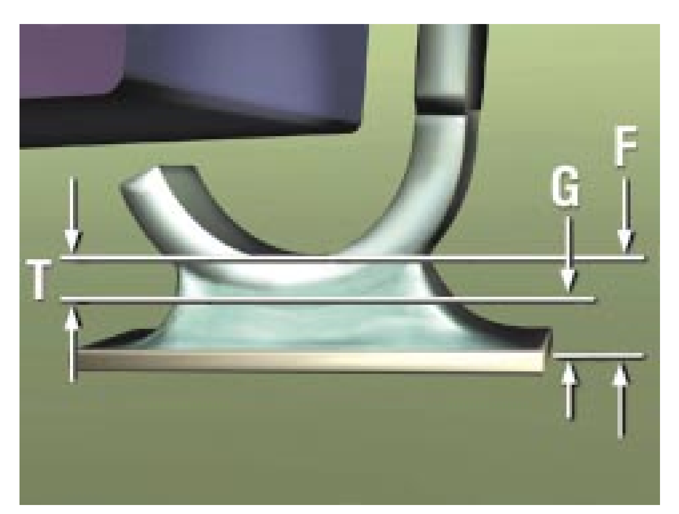


Figure 8-123

Acceptable - Class 3

- Heel fillet height (F) is at least lead thickness (T) plus solder thickness (G).

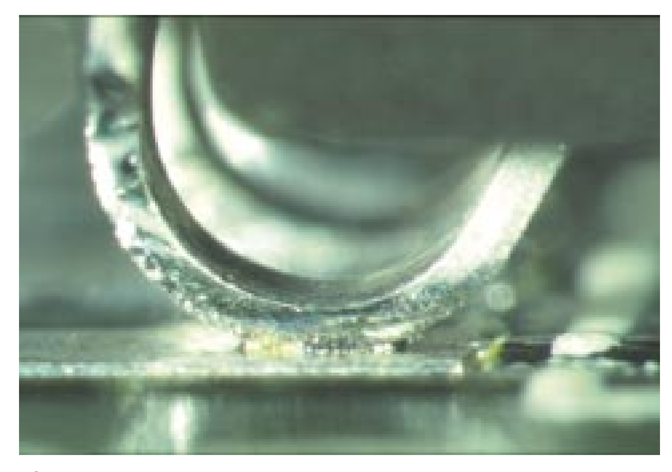


Figure 8-124

Defect - Class 1,2,3

- Heel fillet not wetted.

Defect - Class 1,2

- Heel fillet height (F) less than solder thickness (G) plus 50% lead thickness (T).

Defect - Class 3

- Heel fillet height (F) less than solder thickness (G) plus lead thickness (T).

8.2.7.7 J Leads, Solder Thickness (G)

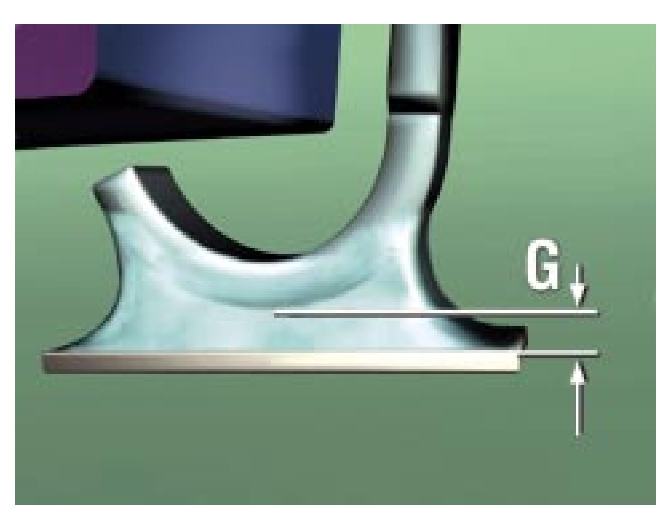


Figure 8-125

Acceptable - Class 1,2,3

- Wetted fillet evident.

Defect - Class 1,2,3

- No wetted fillet.

8.2.7.8 SMT Soldering Anomalies – Coplanarity

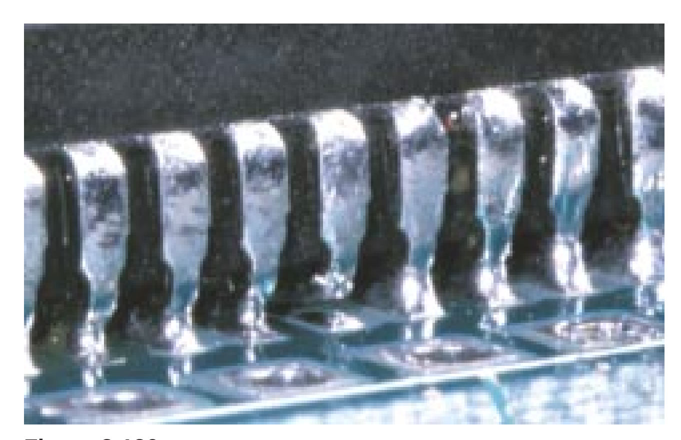


Figure 8-126

Defect - Class 1,2,3

- One lead or series of leads on component is out of alignment and fails to make contact with the land.

8.2.8 Butt/I Connections

Connections formed to leads positioned perpendicular to a circuit land in a butt configuration must meet dimensional and solder fillet requirements in Table 8-8. Post assembly acceptability evaluations should consider the inherent limitation of this component mounting technique to survive operational environments when compared to footed leads or through hole mounting.

For Class 1 and 2 product, leads not having wettable sides by design (such as leads stamped or sheared from preplated stock) are not required to have side fillets. However the design should permit easy inspection of wetting to the wettable surfaces.

Butt connections are not permitted for Class 3 products.

Table 8-8 Dimensional Criteria - Butt/I Connections (Not Applicable to Class 3)

Feature	Dim.	Class 1	Class 2
Maximum Side Overhang	A	25% (W) Note 1	Not permitted
Toe Overhang	B	Not permitted	
Minimum End Joint Width	C	75% (W)	
Minimum Side Joint Length	D	Note 2	
Maximum Fillet Height	E	Note 4	
Minimum Fillet Height	F	0.5 mm [0.0197 in]	
Solder Thickness	G	Note 3	
Lead Thickness	T	Note 2	
Lead Width	W	Note 2	

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, determined by design.
Note 3. Wetting is evident.
Note 4. Maximum fillet may extend into the bend radius. Solder does not touch package body.

8.2.8.1 Butt/I Connections, Maximum Side Overhang (A)

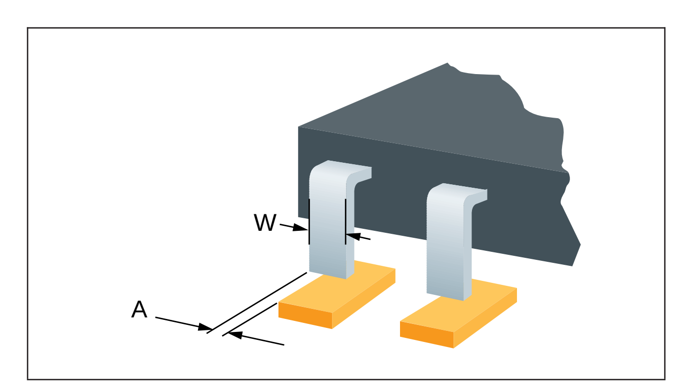


Figure 8-127

Target - Class 1,2

• No side overhang.

Acceptable - Class 1

• Overhang (A) less than 25% lead width (W).

Defect - Class 1

• Overhang (A) exceeds 25% lead width (W).

Defect - Class 2

• Any side overhang (A).

8.2.8.2 Butt/I Connections, Maximum Toe Overhang (B)

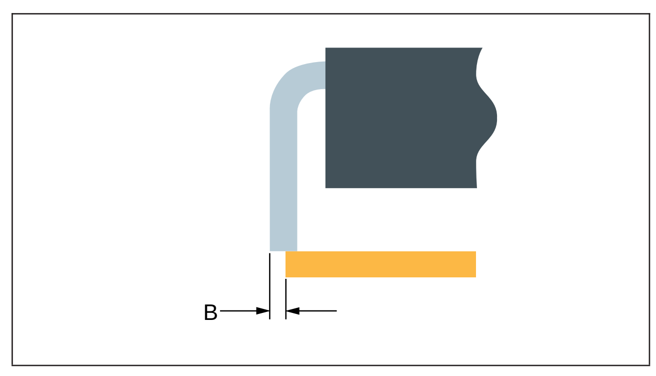


Figure 8-128

Defect - Class 1,2

• Any toe overhang (B).

8.2.8.3 Butt/I Connections, Minimum End Joint Width (C)

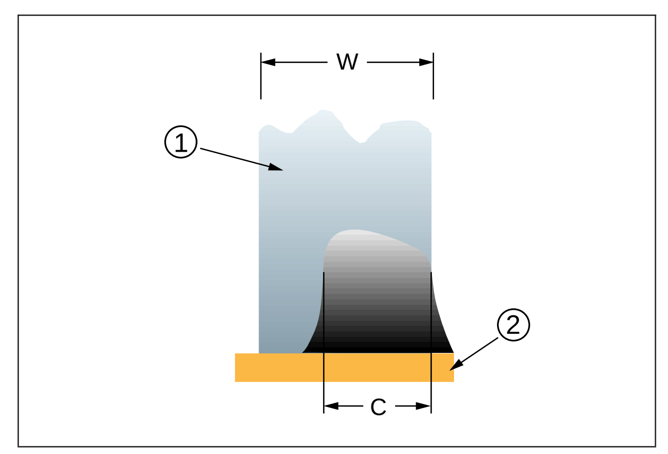


Figure 8-129
1. Lead
2. Land

Target - Class 1,2

• End joint width (C) is greater than lead width (W).

Acceptable - Class 1,2

• End joint width (C) is minimum 75% lead width (W).

Defect - Class 1,2

• End joint width (C) is less than 75% lead width (W).

8.2.8.4 Butt/I Connections, Minimum Side Joint Length (D)

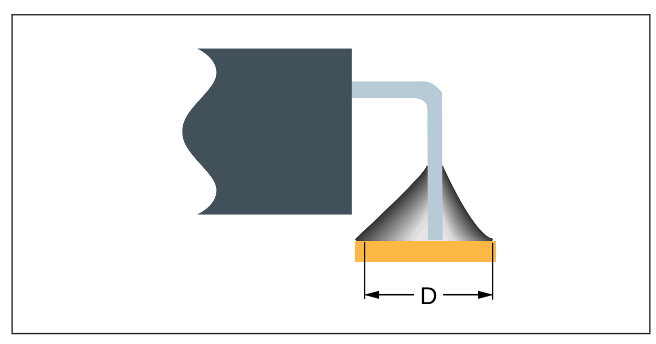


Figure 8-130

Acceptable - Class 1,2

- Minimum side joint length (D) is not a specified parameter.

8.2.8.5 Butt/I Connections, Maximum Fillet Height (E)

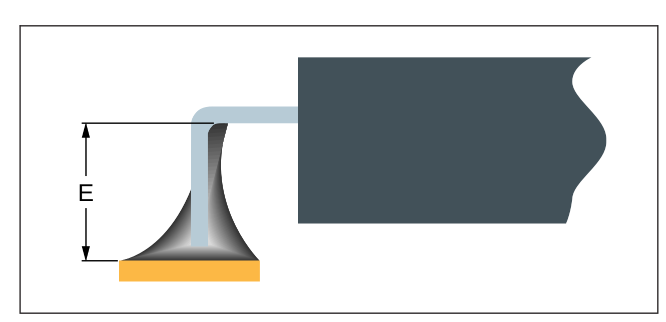


Figure 8-131

Acceptable - Class 1,2

- Wetted fillet evident.

Defect - Class 1,2

- No wetted fillet.
- Solder touches package body.

8.2.8.6 Butt/I Connections, Minimum Fillet Height (F)

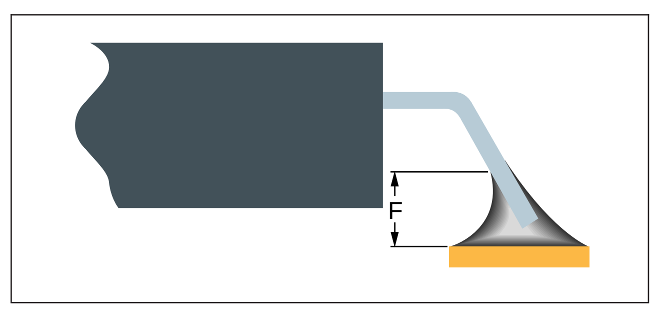


Figure 8-132

Acceptable - Class 1,2

• Fillet height (F) is minimum 0.5 mm [0.02 in].

Defect - Class 1,2

• Fillet height (F) is less than 0.5 mm [0.02 in].

8.2.8.7 Butt/I Connections, Solder Thickness (G)

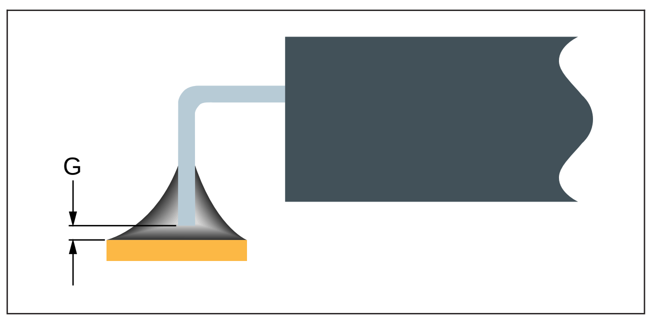


Figure 8-133

Acceptable - Class 1,2

• Wetted fillet evident.

Defect - Class 1,2

• No wetted fillet.

8.2.9 Flat Lug Leads

Connections formed to the leads of power dissipating components with flat lug leads must meet the dimensional requirements of Table 8-9 and Figure 8-134. The design should permit easy inspection of wetting to the wettable surfaces. Nonconformance to the requirements of Table 8-9 is a defect.

Table 8-9 Dimensional Criteria - Flat Lug Leads

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) Note 1	25% (W) Note 1	Not permitted
Maximum Toe Overhang	B	Note 1	Not permitted	
Minimum End Joint Width	C	50% (W)	75% (W)	(W)
Minimum Side Joint Length	D	Note 3	(L)-(M), Note 4	
Maximum Fillet Height	E	Note 2	Note 2	(G) + (T) + 1.0 mm [0.039 in]
Minimum Fillet Height	F	Note 3	Note 3	(G) + (T)
Solder Fillet Thickness	G	Note 3		
Lead Length	L	Note 2		
Maximum Gap	M	Note 2		
Land Width	P	Note 2		
Lead Thickness	T	Note 2		
Lead Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetted fillet is evident.
Note 4. Where the lug is intended to be soldered beneath the component body and the land is designed for the purpose, the lead show evidence of wetting in the gap M.

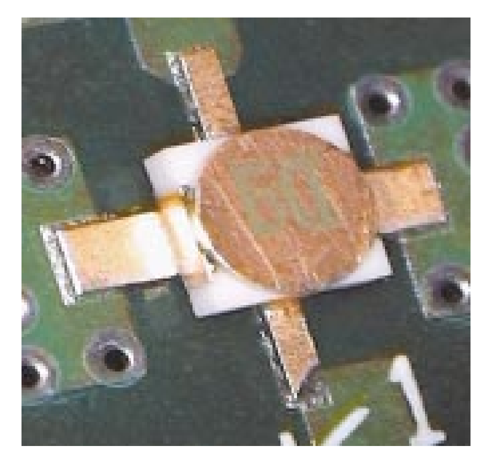


Figure 8-134

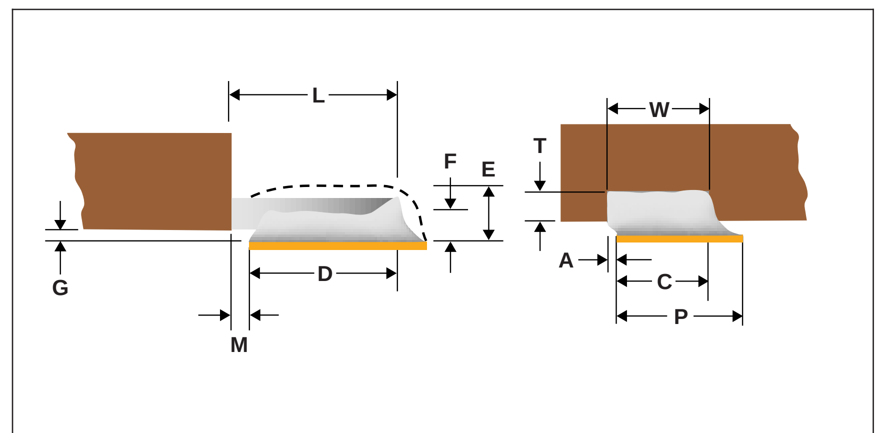


Figure 8-135

8.2.10 Tall Profile Components Having Bottom Only Terminations

Connections formed to the termination areas of tall profile components (component height is more than twice width or thickness, whichever is less) having bottom only terminations must meet the dimensional requirements of Table 8-10 and Figure 8-136. Non-conformance to the requirements of Table 8-10 is a defect.

Table 8-10 Dimensional Criteria - Tall Profile Components Having Bottom Only Terminations

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W); Notes 1, 4	25% (W); Notes 1, 4	Not permitted; Notes 1, 4
Maximum End Overhang	B	Notes 1, 4	Not permitted	
Minimum End Joint Width	C	50% (W)	75% (W)	(W)
Minimum Side Joint Length	D	Note 3	50% (S)	75% (S)
Solder Fillet Thickness	G	Note 3		
Land Length	S	Note 2		
Termination Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. As a function of the component design, the termination may not extend to the component edge, and the component body may overhang the PCB land area. The component solderable termination area does not overhang PCB land area.

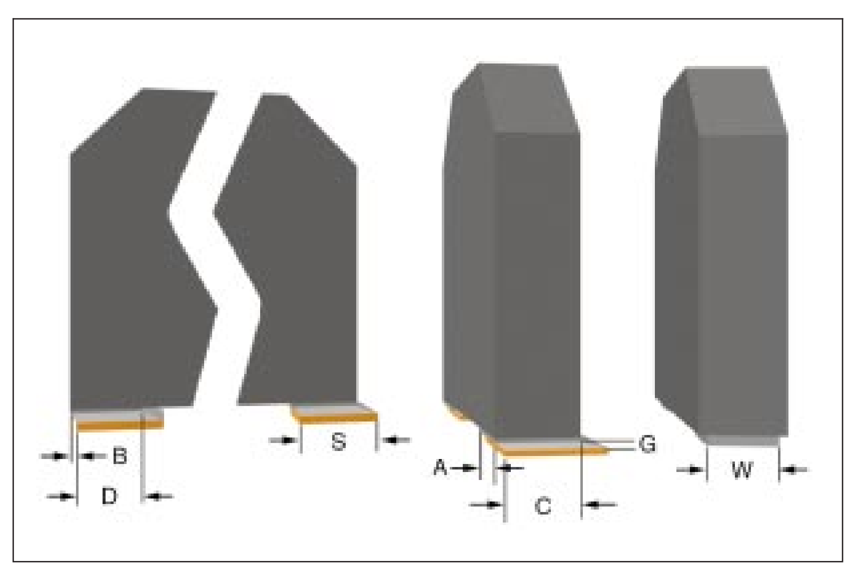


Figure 8-136

8.2.11 Inward Formed L-Shaped Ribbon Leads

Connections formed to components having inward formed L-shaped lead terminations must meet the dimensional and solder fillet requirements of Table 8-11 and Figure 8-137. The design should permit easy inspection of wetting to the wettable surfaces. Nonconformance to the requirements of Table 8-11 is a defect.

Table 8-11 Dimensional Criteria - Inward Formed L-Shaped Ribbon Leads[5]

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) Notes 1, 5		25% (W) or 25% (P), whichever is less; Notes 1, 5
Maximum Toe Overhang	B	Note 1	Not permitted	
Minimum End Joint Width	C	50% (W)		75% (W) or 75% (P), whichever is less
Minimum Side Joint Length	D	Note 3	50% (L)	75% (L)
Maximum Fillet Height	E	(H) + (G) Note 4		
Minimum Fillet Height Notes 5,6	F	Wetting is evident on the vertical surface(s) of the component termination.	(G) + 25% (H) or (G) + 0.5 mm [0.0197 in], whichever is less	
Solder Fillet Thickness	G	Note 3		
Lead Height	H	Note 2		
Land Extension	K	Note 2		
Lead Length	L	Note 2		
Land Width	P	Note 2		
Land Length	S	Note 2		
Lead Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder does not contact the component body on the inside of the lead bend.
Note 5. Where a lead has two prongs, the joint to each prong is to meet all the specified requirements.
Note 6. Designs with via in pad may preclude meeting these criteria. Solder acceptance criteria should be defined between the user and the manufacturer.

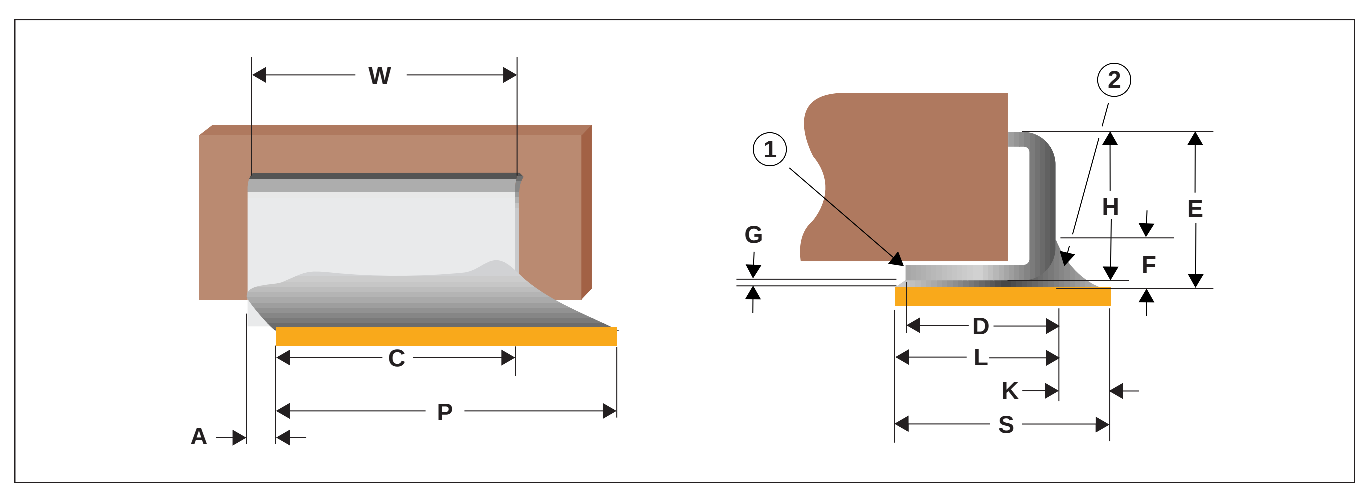


Figure 8-137
1. Toe
2. Heel

8.2.11 Inward Formed L-Shaped Ribbon Leads (cont.)

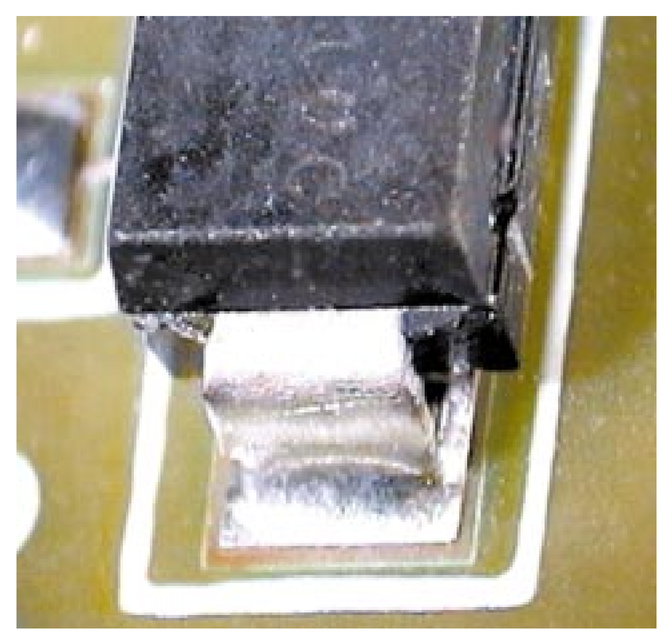


Figure 8-138

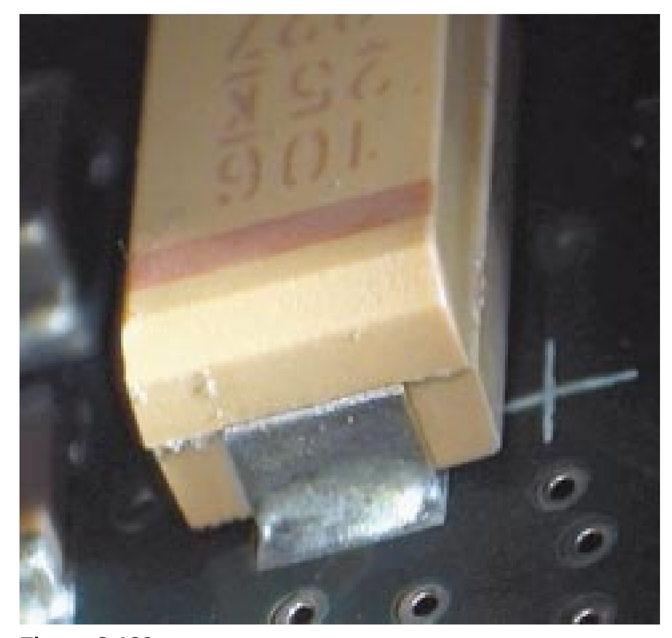


Figure 8-139

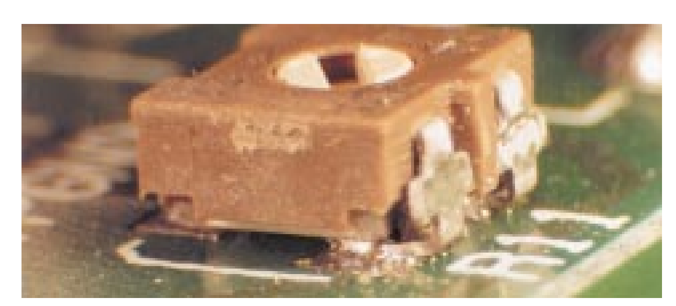


Figure 8-140

Examples of inward formed L-shaped ribbon lead components.

Defect - Class 1,2,3

- Insufficient fillet height.

8.2.12 Surface Mount Area Array

These criteria are intended to apply to devices with solder balls that collapse during reflow.

A BGA criterion defined herein assumes an inspection process is established to determine compliance for both X-Ray and normal visual inspection processes. To a limited extent, this may involve visual assessment, but more commonly requires evaluation of X-Ray images to allow assessment of characteristics that cannot be accomplished by normal visual means. Process development and control is essential for continued success of assembly methods and implementation of materials. Nonconformance to the requirements of Table 8-12 is a defect when visual inspection or X-Ray inspection is performed to verify product acceptance. Process validation can be used in lieu of X-ray/visual inspection provided objective evidence of compliance is available.

BGA process guidance is provided in IPC-7095, which contains recommendations, based from extensive discussion of BGA process development issues.

Note: X-ray equipment not intended for electronic assemblies can damage sensitive components.

Visual inspection requirements:

- When visual inspection is the method used to verify product acceptance the magnification levels of Table 1-2 apply.
- The solder terminations on the outside row (perimeter) of the BGA should be visually inspected whenever practical.
- The BGA needs to align in both X & Y directions with the corner markers on the PCB (if present).
- Absence of BGA solder ball(s) are defects unless specified by design.

Table 8-12 Dimensional Criteria - Surface Mount Area Array Features

Feature	Clause	Classes 1,2,3
Alignment	8.2.12.1	Solder ball offset does not violate minimum electrical clearance.
Solder Ball Spacing	8.2.12.2	Solder ball offset does not violate minimum electrical clearance.
Soldered Connection	8.2.12.3	No solder bridging; BGA solder balls contact and wet to the land forming a continuous elliptical round or pillar connection.
Voids	8.2.12.4	25% or less voiding in a ball x-ray image area.[1,2]
Under-fill or Staking Material	8.2.12.5	Required underfill or staking material is present and completely cured.

Note 1. Design induced voids, e.g., microvia in land, are excluded from this criteria. In such cases acceptance criteria will need to be established between the manufacturer and user.
Note 2. Manufacturers may use test or analysis to develop alternate acceptance criteria for voiding that consider the end-use environment.

8.2.12.1 Surface Mount Area Array – Alignment



Figure 8-141

Target - Class 1,2,3

• Placement of the BGA solder ball is centered and shows no offset of the ball to land centers.

Defect - Class 1,2,3

• Solder ball offset violates minimum electrical clearance.

8.2.12.2 Surface Mount Area Array – Solder Ball Spacing

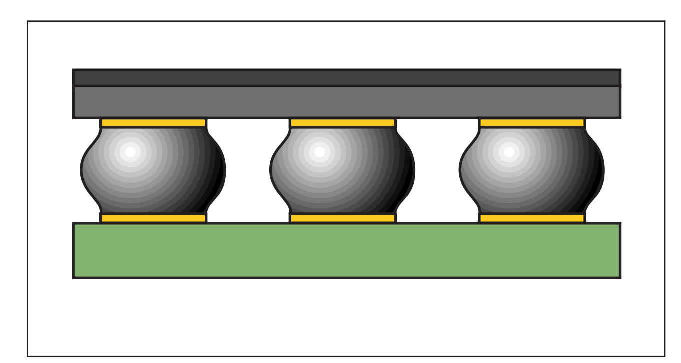


Figure 8-142

Acceptable - Class 1,2,3

• BGA solder balls do not violate minimum electrical clearance (C).

Defect - Class 1,2,3

• BGA solder ball spacing violates minimum electrical clearance.

8.2.12.3 Surface Mount Area Array – Solder Connections

Target - Class 1,2,3

- The BGA solder ball terminations are uniform in size and shape.

Acceptable - Class 1,2,3

- No solder bridging.
- BGA solder balls contact and wet to the land forming a continuous elliptical round or pillar connection.

Process Indicator - Class 2,3

- BGA solder ball terminations are not uniform in size, shape, coloration, and color contrast.

8.2.12.3 Surface Mount Area Array – Solder Connections (cont.)

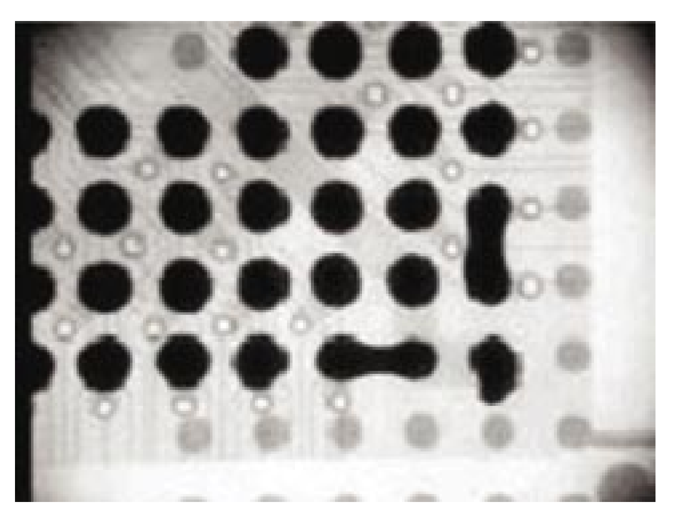


Figure 8-143

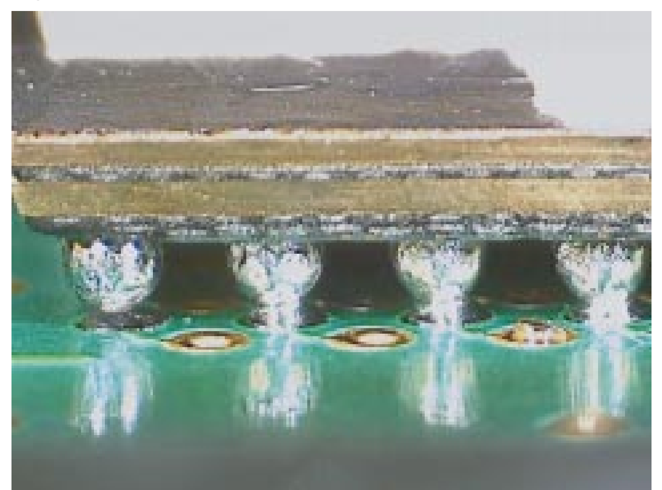


Figure 8-144

Defect - Class 1,2,3

- Visual or x-ray evidence of solder bridging (Figure 8-143).
- A ''waist'' in the solder connection indicating that the solder ball and the attaching solder paste did not flow together (Figure 8-144).
- Incomplete wetting to the land.
- BGA solder ball terminations have incomplete reflow of the solder paste (Figure 8-145).
- Fractured solder connection (Figure 8-146).

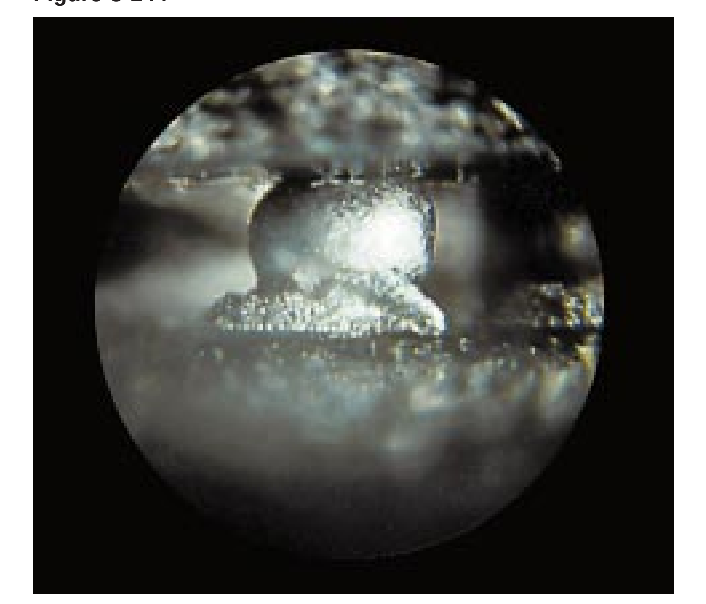


Figure 8-145

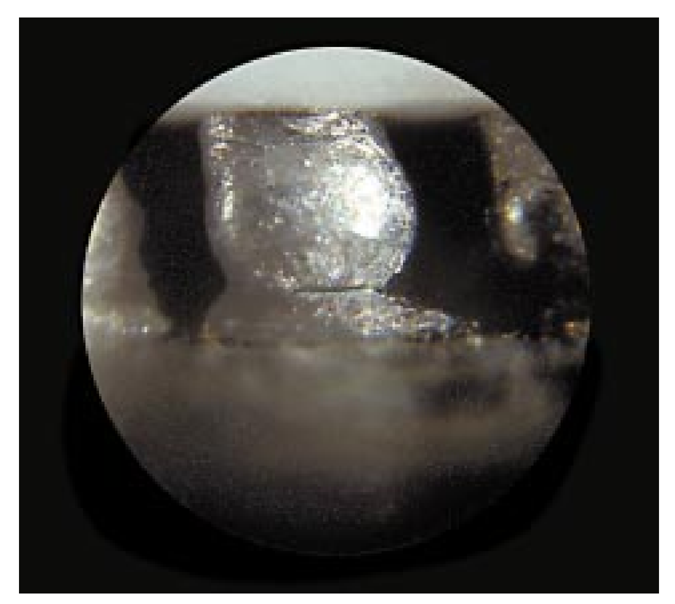


Figure 8-146

8.2.12.4 Surface Mount Area Array – Voids

Design induced voids, e.g., microvia in land, are excluded from this criteria. In such cases acceptance criteria will need to be established between the manufacturer and user.

Manufacturers may use test or analysis to develop alternate acceptance criteria for voiding that consider the end-use environment.

Acceptable - Class 1,2,3

- 25% or less voiding of the ball x-ray image area.

Defect - Class 1,2,3

- More than 25% voiding in the ball x-ray image area.

8.2.12.5 Surface Mount Area Array – Underfill/Staking

Acceptable - Class 1,2,3

- Required underfill or staking material is present.
- Underfill or staking material completely cured.

Defect - Class 1,2,3

- Missing or incomplete underfill or staking material when required.
- Underfill or staking material outside required areas.
- Underfill or staking material not fully cured.

8.2.13 Plastic Quad Flat Pack – No Leads (PQFN)

Some other names for these devices are Microlead Packages, Leadless Plastic Chip Carriers (LPCC), and Quad Flat Pack No-Lead Exposed Pad (QFN-EP). Nonconformance to the requirements of Table 8-13 is a defect.

Table 8-13 Dimensional Criteria - PQFN

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% W, Note 1	25% W, Note 1	
Toe Overhang (outside edge of component termination)	B	Not permitted		
Minimum End Joint Width	C	50% W	75% W	
Minimum Side Joint Length	D	Note 4		
Solder Fillet Thickness	G	Note 3		
Minimum Toe (End) Fillet Height	F	Notes 2, 5		
Termination Height	H	Note 5		
Solder Coverage of Thermal Pad		Note 4		
Land Width	P	Note 2		
Termination Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Not a visually inspectable attribute.
Note 5. Toe (end) surfaces are not required to be solderable. Toe fillets are not required.

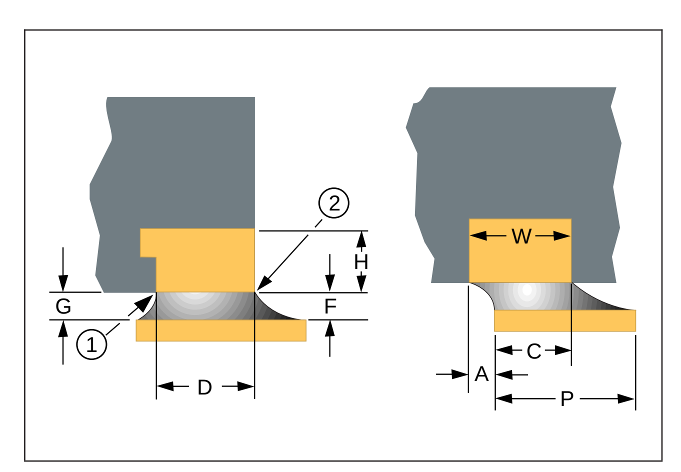



Figure 8-147
1. Heel
2. Toe

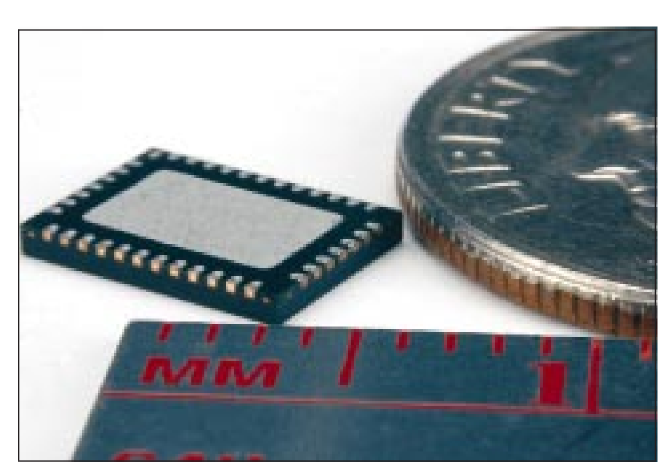


Figure 8-148

8.2.13 Plastic Quad Flat Pack – No Leads (PQFN) (cont.)

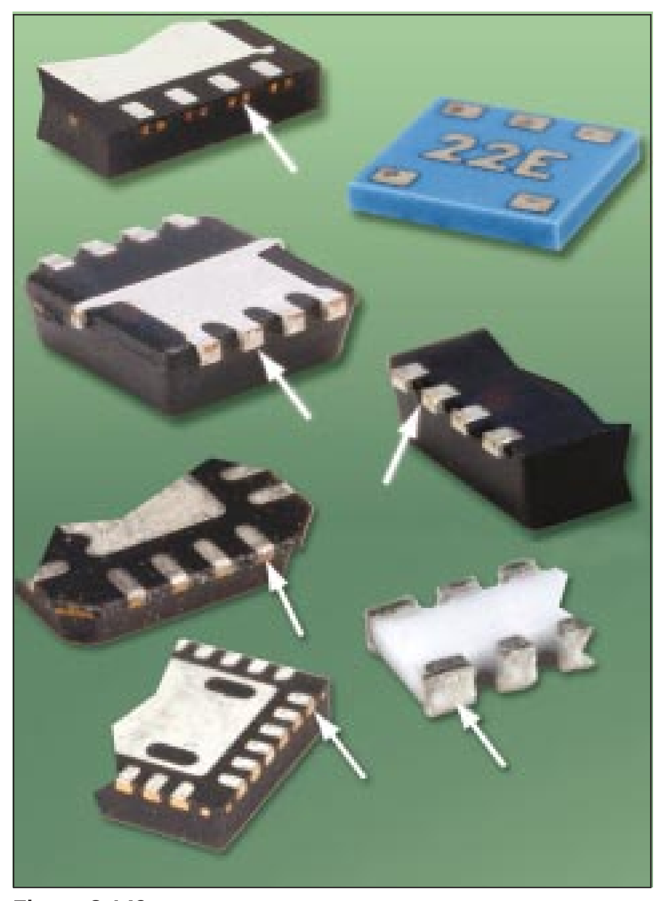


Figure 8-149

There are some package configurations that have no toe exposed or do not have a continuous solderable surface on the exposed toe on the exterior of the package (Figure 8-149 arrows) and a toe fillet will not form, see Figures 8-150 and 8-151.

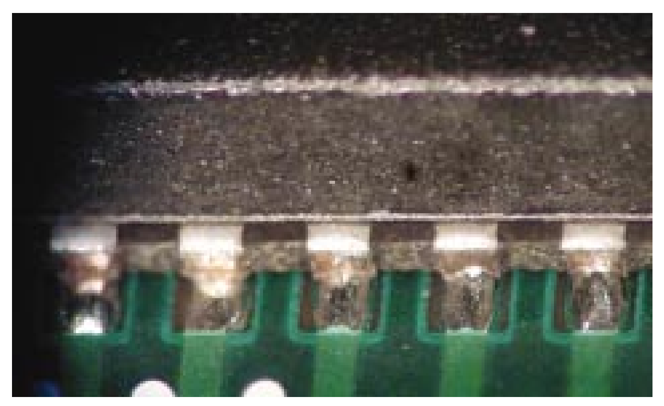



Figure 8-150

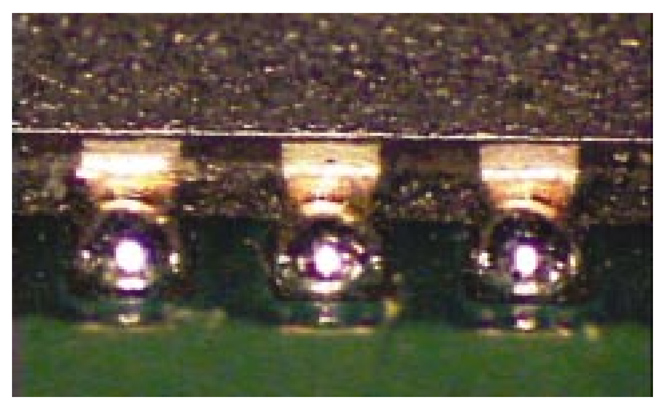


Figure 8-151

8.2.14 Components with Bottom Thermal Plane Terminations

These criteria are specific to packages that employ a bottom thermal plane, such as D-Pak™.

Criteria for nonvisible thermal plane solder connections are not described in this document and will need to be established by agreement between the user and the manufacturer. The thermal transfer plane acceptance criteria are design and process related. Issues to consider include but are not limited to component manufacturer's application notes, solder coverage, voids, solder height, etc. When soldering these types of components voiding in the thermal plane is common.

Note: The criteria for leads other than the thermal plane termination are provided in 8.2.5.

Table 8-14 Dimensional Criteria - Bottom Thermal Plane Terminations

<table>
<tr><th>Feature (all connections except thermal plane)</th><th>Dim.</th><th>Class 1</th><th>Class 2</th><th>Class 3</th></tr>
<tr><td>Maximum Side Overhang</td><td>A</td><td colspan="3" rowspan="7">See 8.2.5</td></tr>
<tr><td>Toe Overhang (outside edge of component termination)</td><td>B</td></tr>
<tr><td>Minimum End Joint Width</td><td>C</td></tr>
<tr><td>Minimum Side Joint Length</td><td>D</td></tr>
<tr><td>Maximum Heel Fillet Height</td><td>E</td></tr>
<tr><td>Minimum Heel Fillet Height</td><td>F</td></tr>
<tr><td>Solder Fillet Thickness</td><td>G</td></tr>
<tr><td>Feature (only for the thermal plane connection)</td><td></td><td colspan="3">Class 1,2,3</td></tr>
<tr><td>Thermal Plane Side Overhang (Figure 8-153)</td><td></td><td colspan="3">Not greater than 25% of termination width.</td></tr>
<tr><td>Thermal Plane End Overhang</td><td></td><td colspan="3">No overhang.</td></tr>
<tr><td>Thermal Plane End Joint Width</td><td></td><td colspan="3">100% wetting to land in the end-joint contact area.</td></tr>
</table>

8.2.14 Components with Bottom Thermal Plane Terminations (cont.)

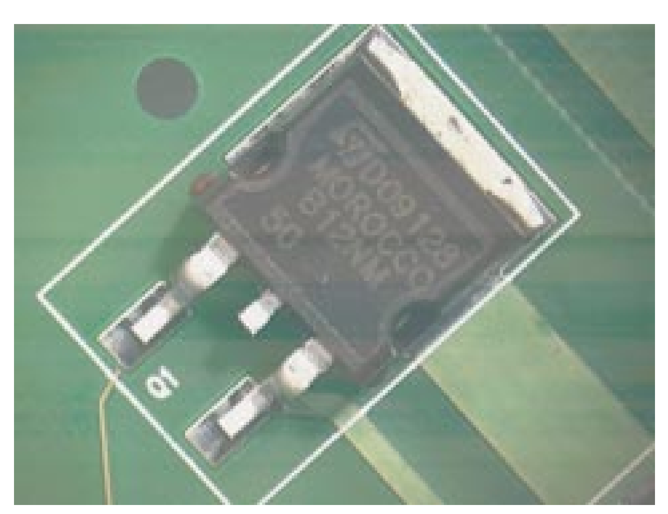


Figure 8-152

Target - Class 1,2,3

- No thermal plane side overhang.
- Thermal plane termination edges have 100% wetting.

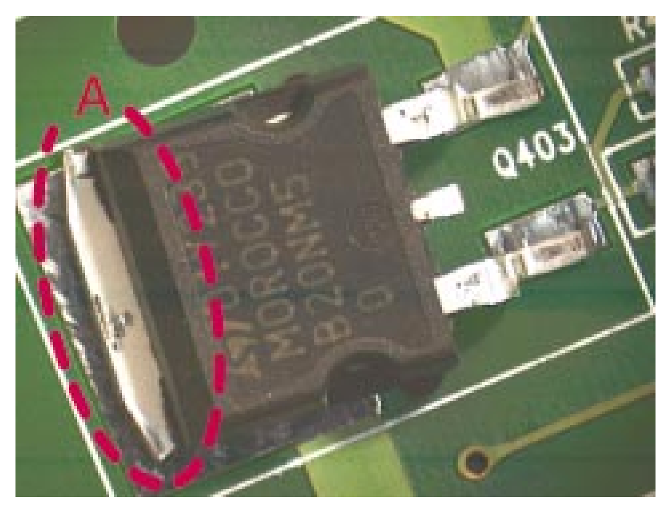


Figure 8-153

Acceptable - Class 1,2,3

- Thermal plane termination (A) side overhang is not greater than 25% of termination width.
- End joint width of the thermal plane end termination has 100% wetting to land in the contact area.

Defect - Class 1,2,3

- Side overhang of thermal plane termination is greater than 25% of termination width.
- End of thermal plane termination overhangs land.
- End joint width of the thermal plane end termination has less than 100% wetting to land in the contact area.

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9 Component Damage

The following topics are addressed in this section:

9.1 Loss of Metallization & Leaching

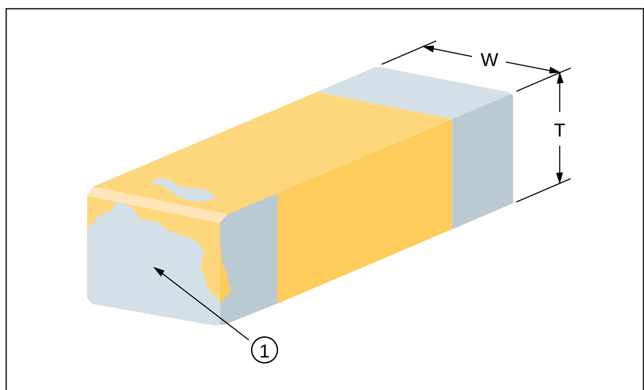


Figure 9-1

1. Leaching

Figure 9-2

1. Metallization missing
2. Adhesive coating
3. Resistive element
4. Substrate (ceramic/alumina)
5. Terminal end

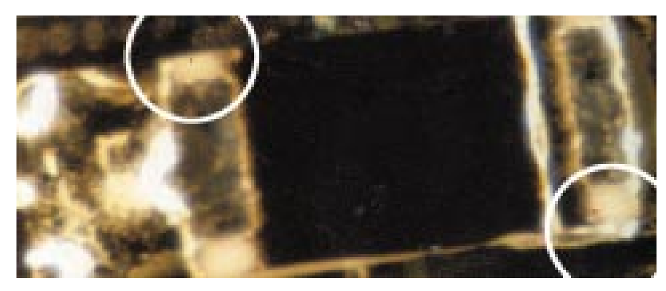


Figure 9-3

Acceptable - Class 1,2,3

- Leaching (Figures 9-1, 2) on any edge less than 25% of the component width (W) or the component thickness (T), Figure 9-3.
- Maximum of 50% of metallization loss of top metallization area (for each terminal end), Figures 9-1, 2.

9.1 Loss of Metallization & Leaching (cont.)

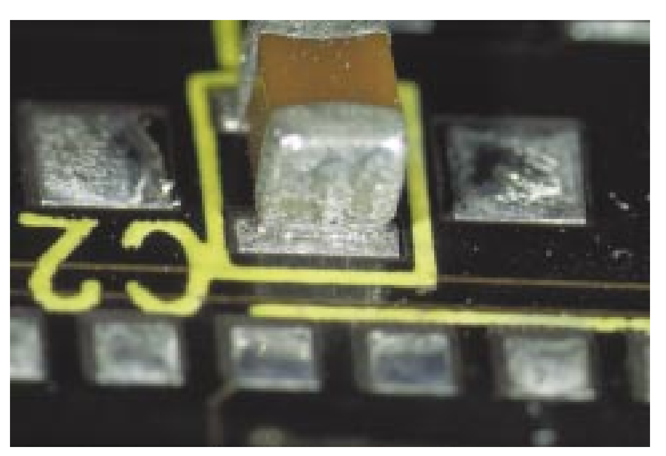


Figure 9-4

Defect - Class 1,2,3

- Leaching of the terminal end face exposing the ceramic, Figure 9-4.
- Leaching exceeding 25% of component width (W) or component thickness (T), Figures 9-1 and 9-5.
- Metallization loss exceeds 50% of top area, Figures 9-5 and 9-6.
- Irregular shapes exceeding maximum or minimum dimensions for that component type, Figures 9-2, 9-3 and 9-6.



Figure 9-5


Figure 9-6

9.2 Chip Resistor Element

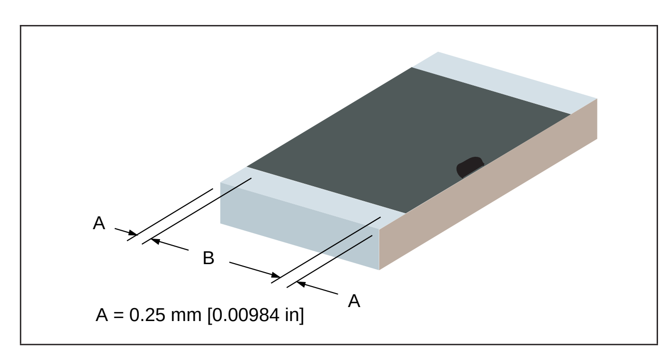


Figure 9-7

Acceptable - Class 1,2,3

- For chip resistors, any chip-out (nick) of the top surface (adhesive coating) of 1206 and larger component is less than 0.25 mm [0.00984 in] from the edge of the component.
- No damage to the resistive element in area B.

Defect - Class 1,2,3

- Any chip-outs in resistive elements.

9.3 Leaded/Leadless Devices

These criteria are applicable to leaded and leadless devices.

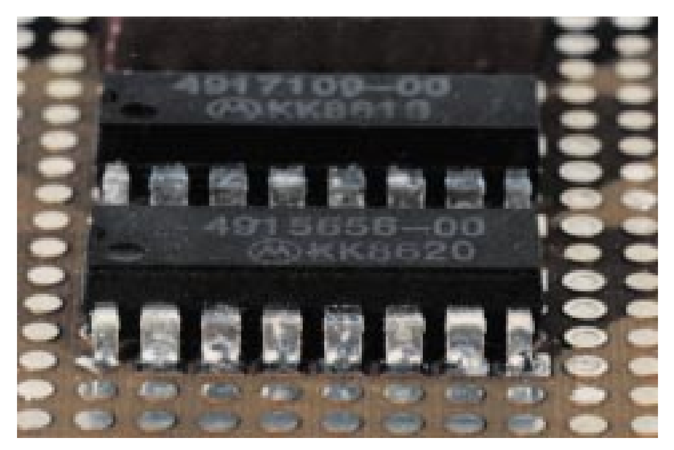


Figure 9-8

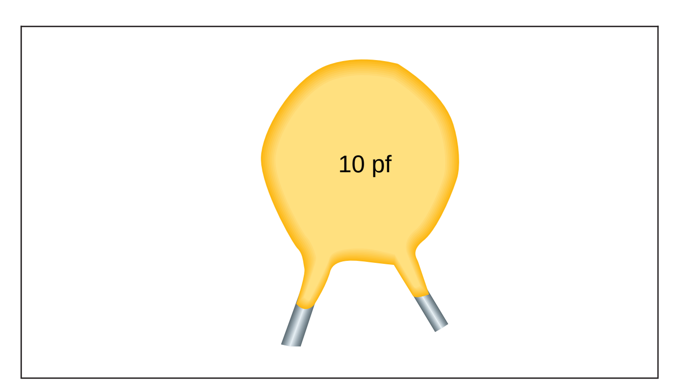


Figure 9-9

Target - Class 1,2,3

- Finish not damaged.
- Component bodies are free of scratches, cracks, chips, and crazing.
- ID markings are legible.

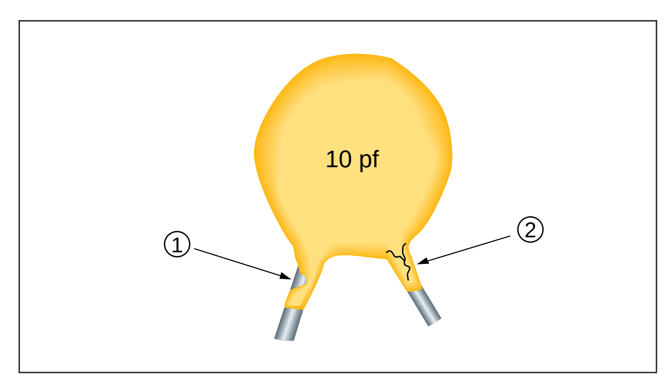


Figure 9-10
1. Chip
2. Crack

Acceptable - Class 1,2,3

- Minor surface scratches, cuts, or chips that do not expose the component substrate or active area.
- Structural integrity is not compromised.
- No evidence of cracks or damage to the lid or lead seals of a component.

9.3 Leaded/Leadless Devices (cont.)

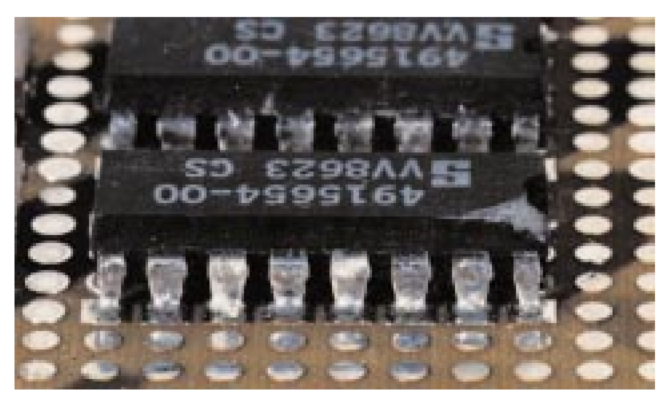


Figure 9-11

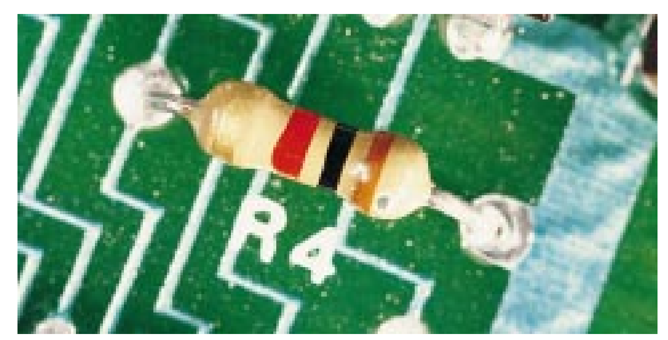


Figure 9-12



Figure 9-13

Acceptable - Class 1
Process Indicator - Class 2,3

- Indentations or chipouts on **plastic** body components do not enter lead seal or lid seals or expose an internal functional element, Figures 9-11, 9-12.
- Component damage has not removed required identification.
- Component insulation/sleeving has damage provided that:
  - Damaged area shows no evidence of increasing.
  - Exposed component conductive surface provides no danger of shorting to adjacent components or circuitry.

Process Indicator - Class 2
Defect - Class 3

- Chipouts on edges of **ceramic** body components do not:
  - Enter lead or lid seals.
  - Have evidence of cracks extending from the chipout.

9.3 Leaded/Leadless Devices (cont.)

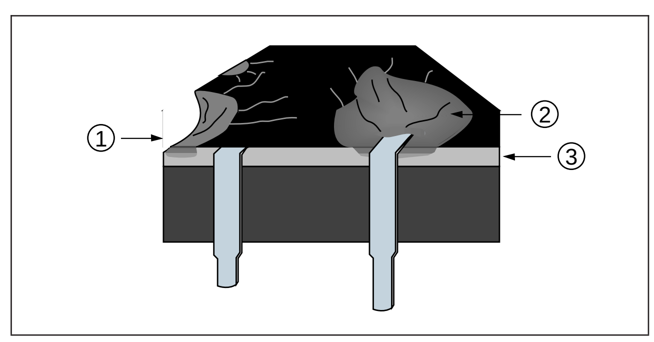


Figure 9-14

1. Chip enters seal
2. Exposed lead
3. Seal



Figure 9-15

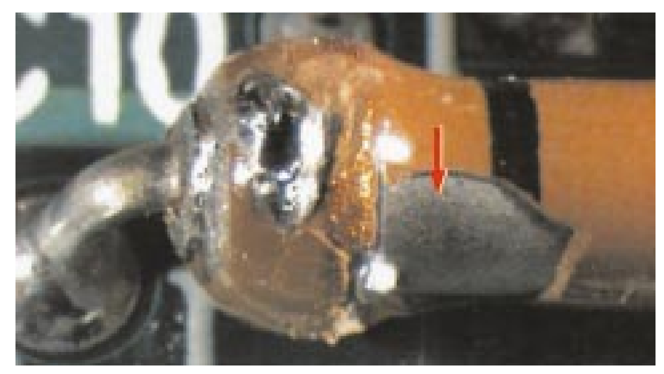


Figure 9-16

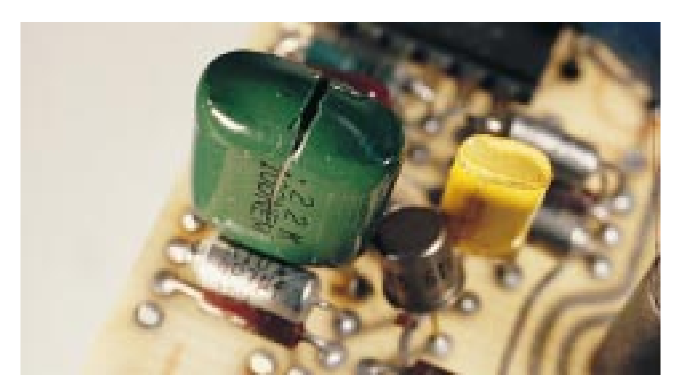


Figure 9-17

Defect - Class 1,2,3

- Chip out or crack:
  - Enters into the seal, Figure 9-14.
  - Exposes the lead in an area not normally exposed, Figure 9-14.
  - Exposes an internal functional element or compromise integrity of component, Figures 9-15, 9-16, 9-17, 9-18, 9-19, 9-20.
- There are cracks leading from the chip out on a ceramic body component, Figure 9-14.
- Chips or cracks in glass body, Figure 9-18.
- Cracked or damaged glass bead (not shown).
- Required identification is missing due to component damage.
- The insulating cover is damaged to the extent that the internal functional element is exposed or the component shape is deformed, Figure 9-16.
- Damaged area shows evidence of increasing.
- Damage permits potential shorting to adjacent components or circuitry.

9.3 Leaded/Leadless Devices (cont.)



Figure 9-18

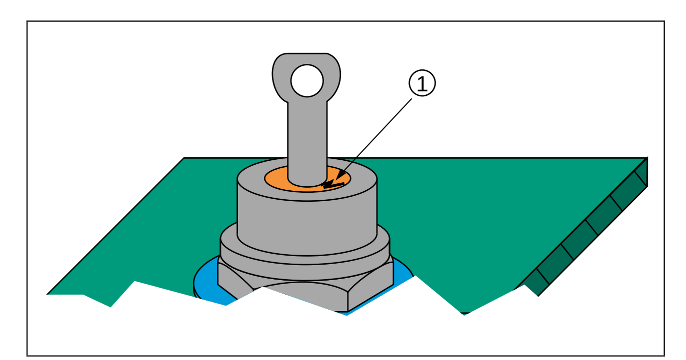


Figure 9-19
1. Cracked insulator

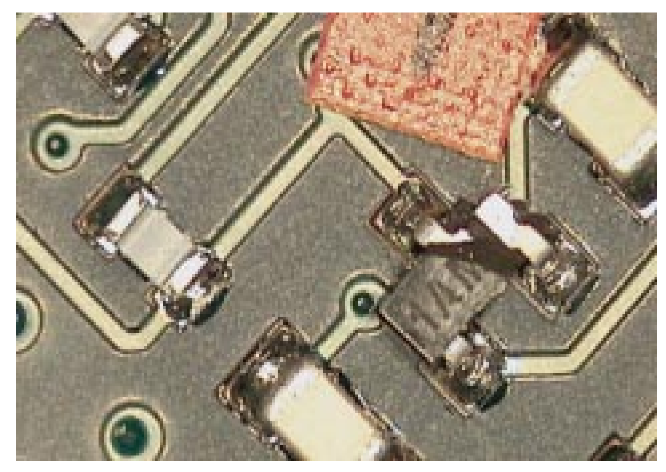
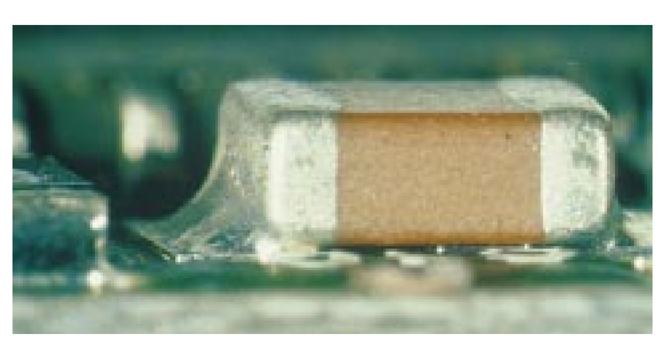


Figure 9-20

9.4 Chip Components


Figure 9-21

Target - Class 1,2,3

- No nicks, cracks, or stress fractures.

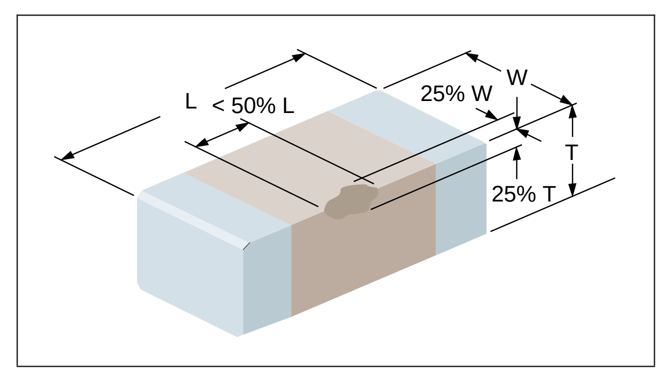


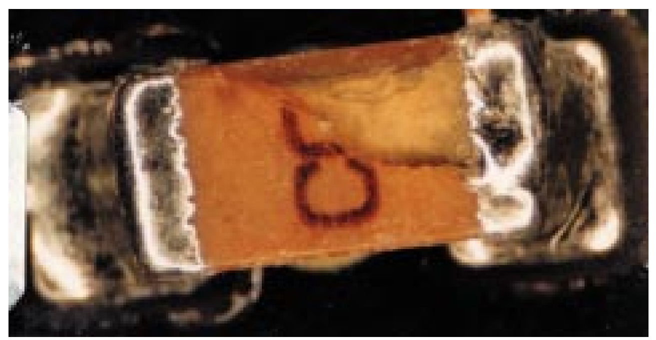
Figure 9-22

Acceptable - Class 1,2

- Nicks or chip-outs not greater than dimensions stated in Table 9-1, each considered separately.

Table 9-1 Chip-Out Criteria

(T)	25% of the thickness
(W)	25% of the width
(L)	50% of the length


Figure 9-23

Defect - Class 1,2
(Figures 9-22 - 27)

- Any nick or chip-out that exposes the electrodes.
- Cracks, nicks or any type of damage in glass bodied components.
- Any chip-outs in resistive elements.
- Any cracks or stress fractures.
- Damage in excess of Table 9-1.

9.4 Chip Components (cont.)

Defect - Class 3

- Any nick, crack, chipout, or stress fracture.

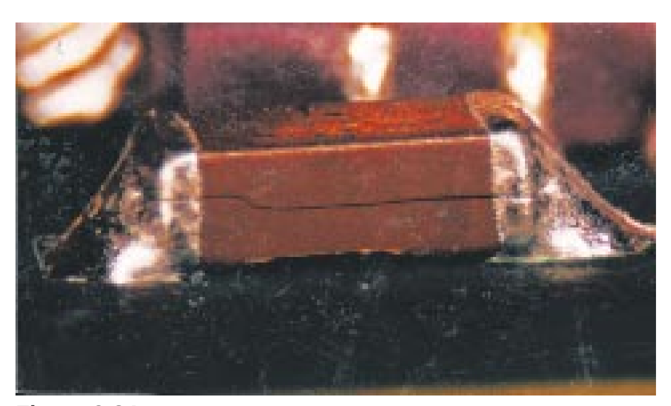


Figure 9-24

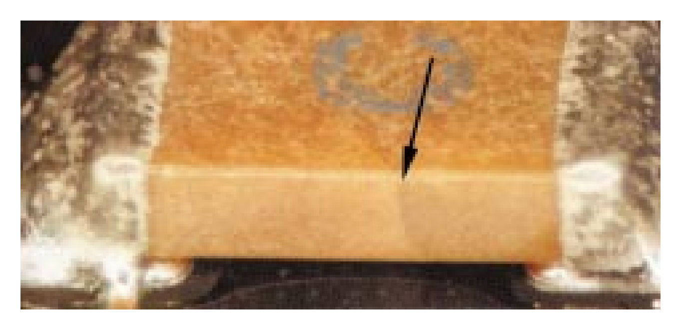


Figure 9-25

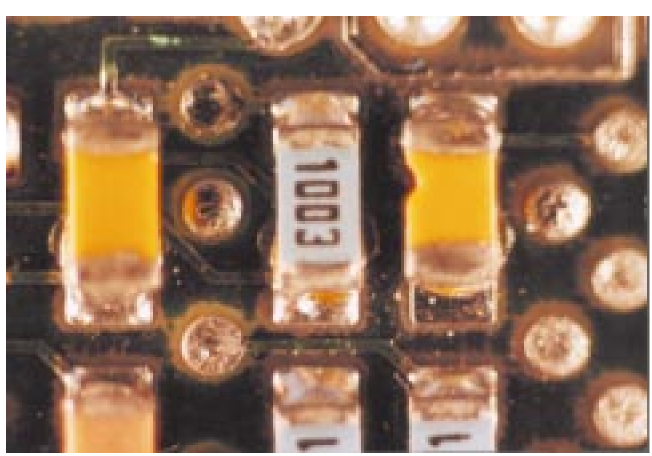


Figure 9-26

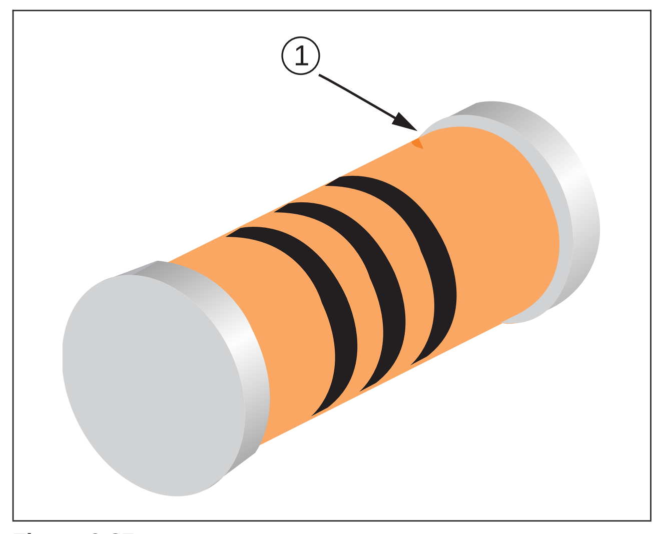


Figure 9-27

1. Nick

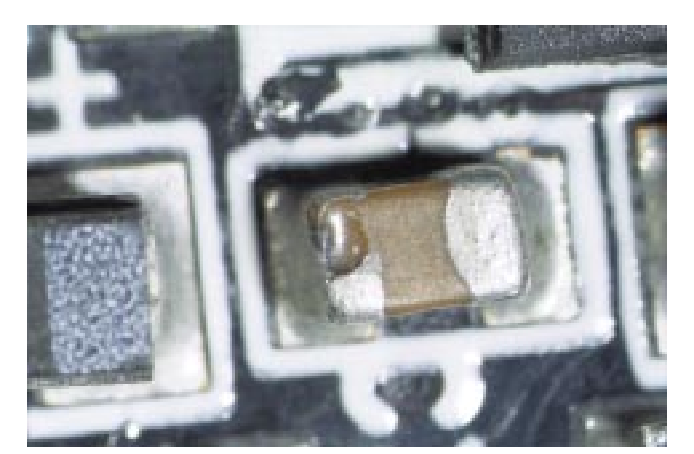


Figure 9-28

9.5 Connectors

These criteria cover the plastic molded housings/shrouds which are used primarily as a guide for the mating connector. Connector pins are typically held by interference fit in a housing. The connector is inserted into a PCB and shrouds may be installed on the reverse side of the connector pins if required. Visual inspection of housings and shrouds includes physical damage such as cracks and deformation.

Target - Class 1,2,3

- No discernable physical damage.
- No burrs on housing/shroud.
- No cracks in housing/shroud.

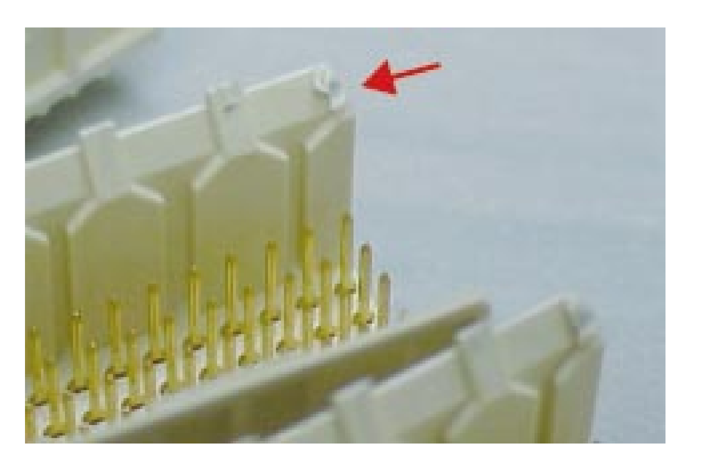


Figure 9-29

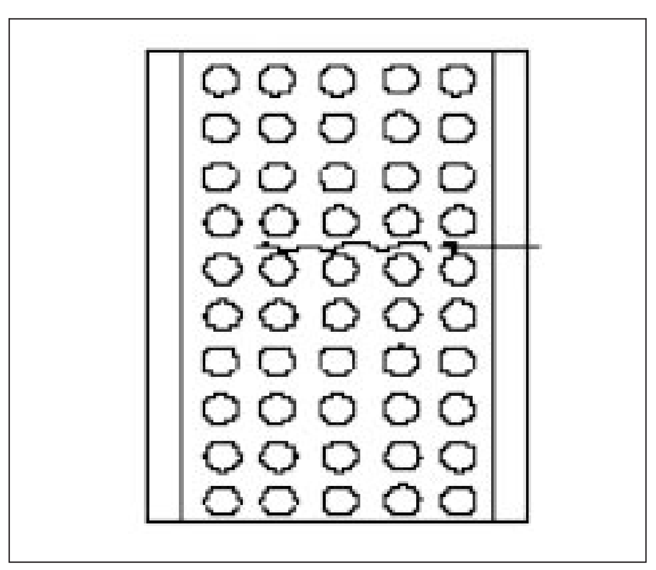


Figure 9-30

Acceptable - Class 1,2

- Plastic burrs on housing but still attached (have not broken loose).
- Crack in noncritical area (does not impact integrity of the housing/shroud).

Acceptable - Class 3

- No cracks in housing/shroud.

9.5 Connectors (cont.)

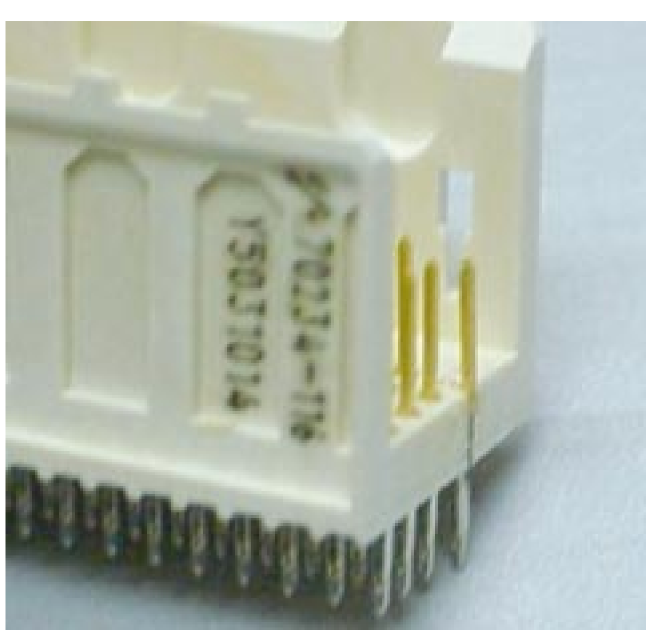


Figure 9-31

Defect - Class 1,2,3

- Cracks or other deformations that impact the mechanical integrity or functionality of the housing.
- Cracks occurring at the sidewall-to-base interface.



Figure 9-32



Figure 9-33

Acceptable - Class 1,2,3

- No evidence of burn or char.
- Minor chips, scrapes, scratches or melting that does not affect form, fit or function.

Process Indicator - Class 2,3

- Slight discoloration.

Defect - Class 1,2,3

- Evidence of burning or charring.
- Changes in shape, chips, scrapes, scratches, melting or other damage that affect form, fit or function.

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10 Printed Circuit Boards and Assemblies

The following topics are addressed in this section:

10.1 Gold Fingers

See IPC-A-600 and IPC-6010 (Series) for further criteria on gold fingers.

Inspection is typically accomplished without magnification or lighting aids. However, there may be instances where these aids are needed; e.g., pore corrosion, surface contamination.

Critical contact area (any portion of the fingers that contacts the mating surface of the connector) is dependent upon the connector system scheme being used by the manufacturer. The documentation should identify those particular dimensions.

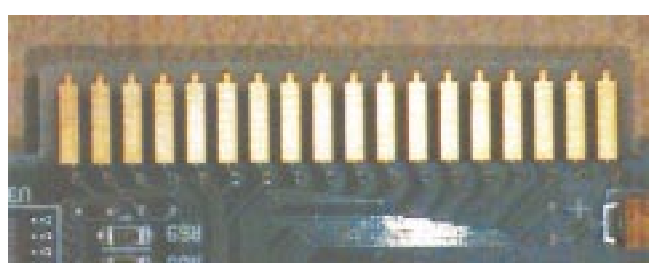


Figure 10-1

Target - Class 1,2,3

- No contamination on gold fingers.

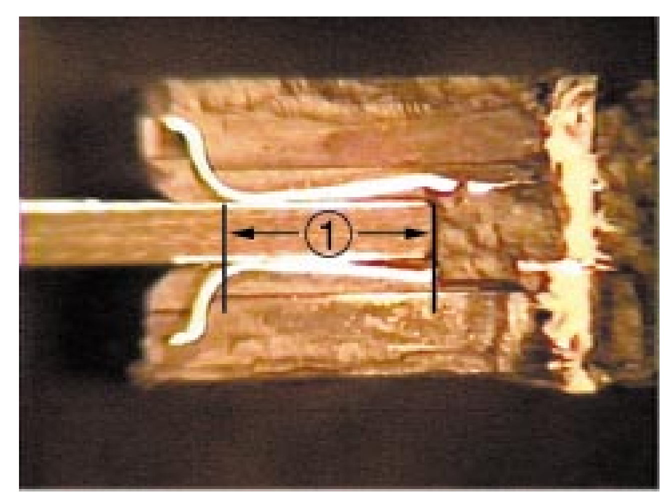


Figure 10-2

1. Critical contact area of edge fingers in contact with spring contact.

Acceptable - Class 1,2,3

- Solder is allowed in noncontact areas of fingers.

10.1 Gold Fingers (cont.)

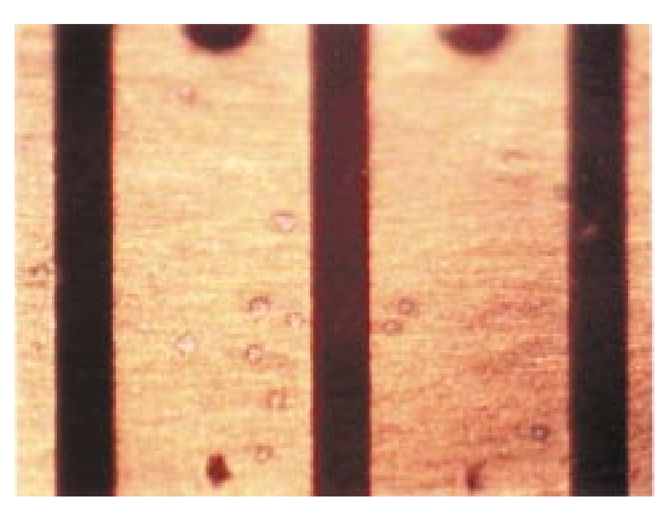


Figure 10-3

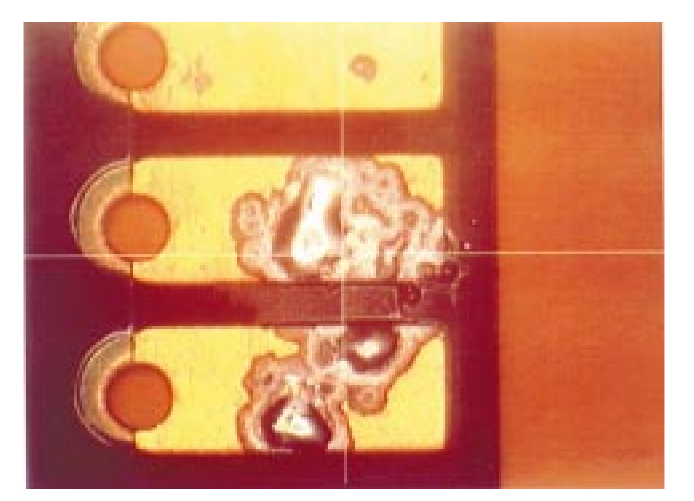


Figure 10-4

Defect - Class 1,2,3

- Solder, any metal other than gold, or any other contamination in the critical contact area of the fingers.

10.2 Laminate Conditions

The purpose of this section is to help the reader better understand the problem of recognizing laminate defects. In addition to providing detailed drawings and photographs to help identify common laminate defects, this section also provides acceptance criteria for the presence of measles on the board assembly.

This section is based on the requirements of IPC-A-600.

Note: This document takes exception to the bare board measling criteria of some versions of IPC-A-600 and IPC-6012.

The identification of laminate defects can be confusing. To help identify defect conditions, please refer to the following pages where definitions, illustrations, and photographs have been provided that define and identify the following conditions and establish acceptance criteria:

- measling
- crazing
- blistering
- delamination
- weave texture
- weave exposure
- haloing

It is important to note that laminate defect conditions may become apparent when the fabricator receives the material from the laminator, or during the fabrication or assembly of the printed board.

10.2.1 Laminate Conditions – Measling and Crazing

This is an inherent condition in the laminate caused during processing the board or assembly.

Measling or crazing that occurs as a result of an assembly process (e.g., use of press fit pins, reflow soldering, etc.) will usually not increase.

Where measles are present that violate minimum electrical clearance, additional performance testing or dielectric resistance measurements may be required considering the product performance envelope; e.g., moisture environments, low atmosphere.

Where the substrate includes embedded components additional criteria may need to be defined.

Measling - An internal condition occurring in laminated base material in which the glass fibers are separated from the resin at the weave intersection. This condition manifests itself in the form of discrete white spots or crosses below the surface of the base material, and is usually related to thermally induced stress.

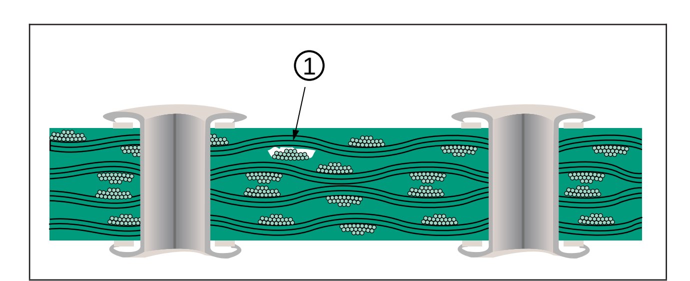


Figure 10-5
1. Measling



Figure 10-6

Target - Class 1,2,3

- No evidence of measling.

Acceptable - Class 1

- The criteria for measling is that the assembly is functional.

Acceptable - Class 2,3

- Measled areas in laminate substrates do not exceed 50% of the physical spacing between internal conductors.

Process Indicator - Class 2
Defect - Class 3

- Measled areas in laminate substrates exceed 50% of the physical spacing between internal conductors.

Note: This document takes exception to the bare board measling criteria of some versions of IPC-A-600 and IPC-6012.

10.2.1 Laminate Conditions – Measling and Crazing (cont.)

Crazing - An internal condition occurring in laminated base material in which the glass fibers are separated from the resin at the weave intersections. This condition manifests itself in the form of connected white spots or crosses below the surface of the base material and is usually related to mechanically induced stress.

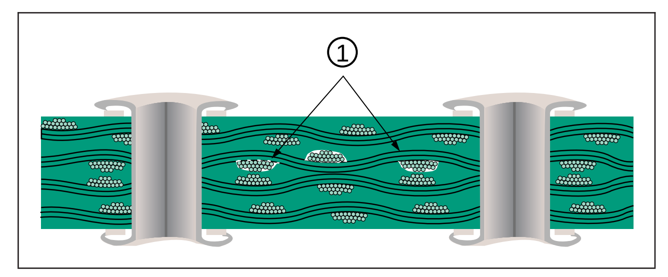


Figure 10-7
1. Crazing

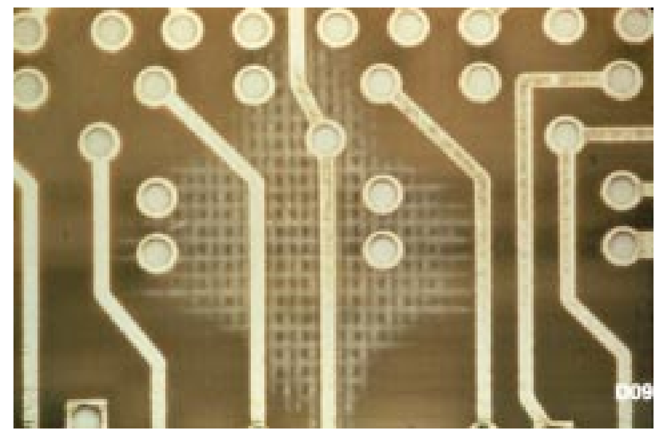


Figure 10-8

Target - Class 1,2,3

- No evidence of crazing.

Acceptable - Class 1

- The criteria for crazing are that the assembly is functional.

Acceptable - Class 2,3

- Crazed areas in laminate substrates do not exceed 50% of the physical spacing between noncommom conductors.
- Crazing does not reduce spacing below minimum electrical clearance.

Defect - Class 2,3

- Crazed areas in laminate substrates exceed 50% of the physical spacing between internal conductors.
- Spacing is reduced below minimum electrical clearance.
- Crazing at the edge of the board reduces the minimum distance between board edge and conductive pattern, or more than 2.5 mm [0.0984 in] if not specified.

10.2.2 Laminate Conditions – Blistering and Delamination

In general, delamination and blistering occurs as a result of an inherent weakness of the material or process. Delamination or blistering between nonfunctional areas and functional areas may be acceptable provided that the imperfections are nonconductive and that other criteria are met.

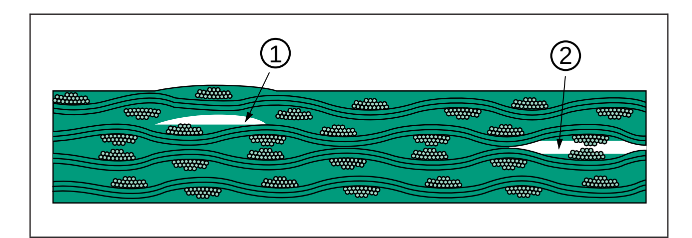


Figure 10-9
1. **Blistering**
2. **Delamination**

Blistering - Delamination in the form of a localized swelling and separation between any of the layers of a lamination base material, or between base material and conductive foil or protective coating.

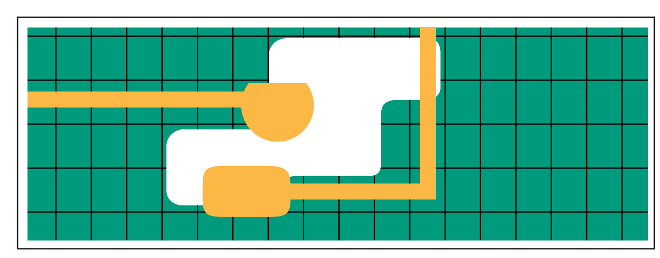


Figure 10-10

Delamination - A separation between plies within a base material, between a base material and a conductive foil or any other planar separation with a printed board.

10.2.2 Laminate Conditions – Blistering and Delamination (cont.)

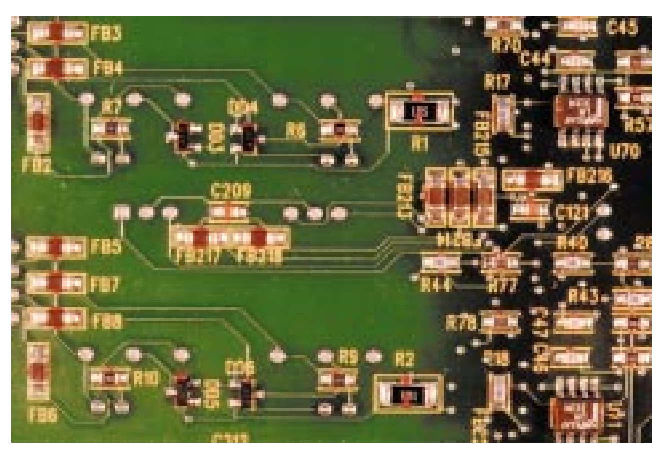


Figure 10-11

Target - Class 1,2,3

- No blistering or delamination.

Acceptable - Class 1,2,3

- The blistering/delamination does not bridge more than 25% of the distance between plated-through holes or internal conductors.

10.2.2 Laminate Conditions – Blistering and Delamination (cont.)

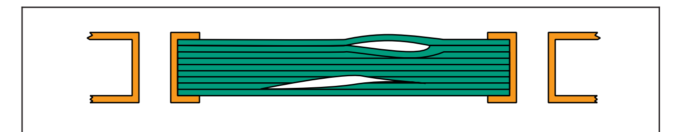


Figure 10-12

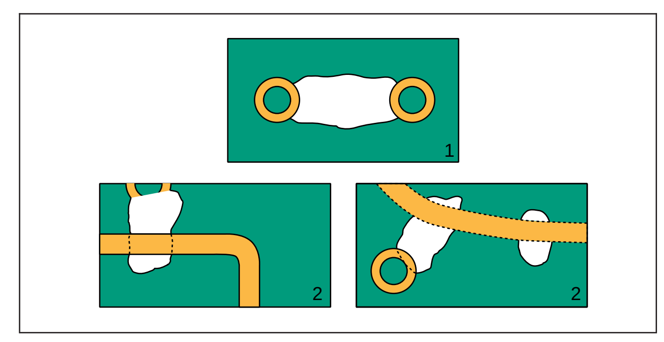


Figure 10-13



Figure 10-14



Figure 10-15

Defect - Class 1,2,3

- Blister/delamination exceeds 25% of the distance between plated-through holes or internal conductors.
- The blistering/delamination reduces the space between conductive patterns below the minimum electrical clearance.

Note: Blisters or delamination areas may increase during assembly or operation. Separate criteria may need to be established.

10.2.3 Laminate Conditions – Weave Texture/Weave Exposure

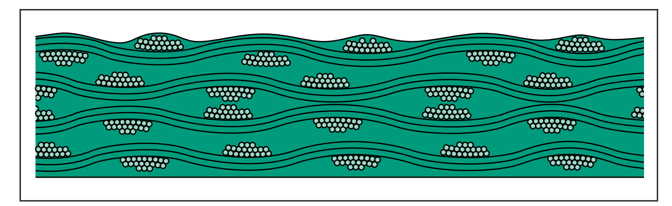


Figure 10-16

Weave Texture - A surface condition of base material in which a weave pattern of glass cloth is apparent although the unbroken fibers are completely covered with resin.

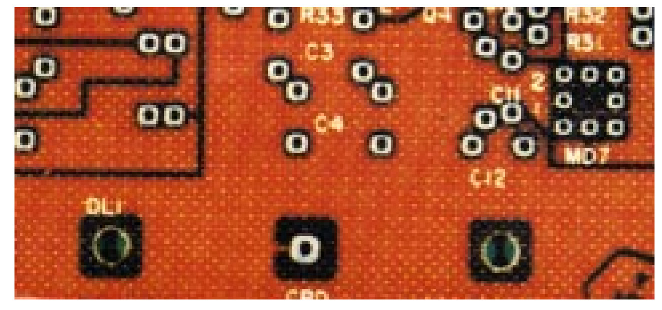


Figure 10-17

Acceptable - Class 1,2,3

- Weave texture is an acceptable condition in all classes but is confused with weave exposure because of similar appearance.

Note: Microsection may be used as a reference for this condition.

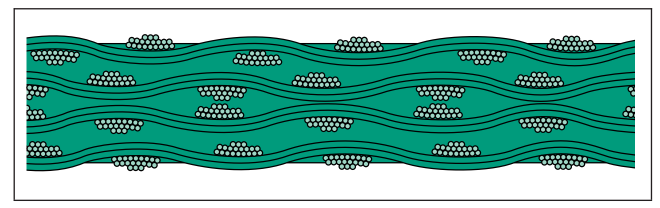


Figure 10-18

Weave Exposure - A surface condition of base material in which the unbroken fibers of woven glass cloth are not completely covered by resin.

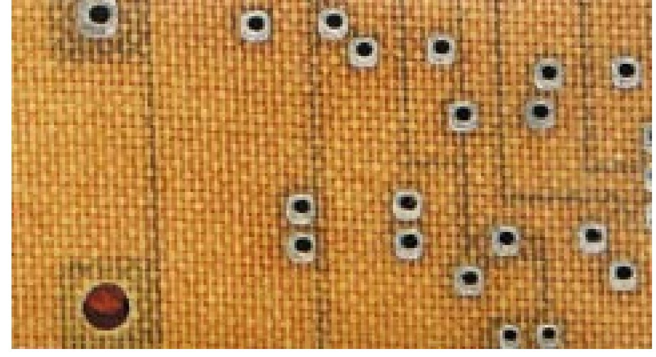


Figure 10-19

Target - Class 1,2,3

- No weave exposure.

Acceptable - Class 1,2,3

- Weave exposure does not reduce the spacing between conductive patterns below specification minimums.

Defect - Class 1,2,3

- Weave exposure reduces the spacing between conductive patterns to less than the minimum electrical clearance.

10.2.4 Laminate Conditions – Haloing and Edge Delamination

Haloing - A condition existing in the base material in the form of a light area around holes or other machined areas on or below the surface of the base material.

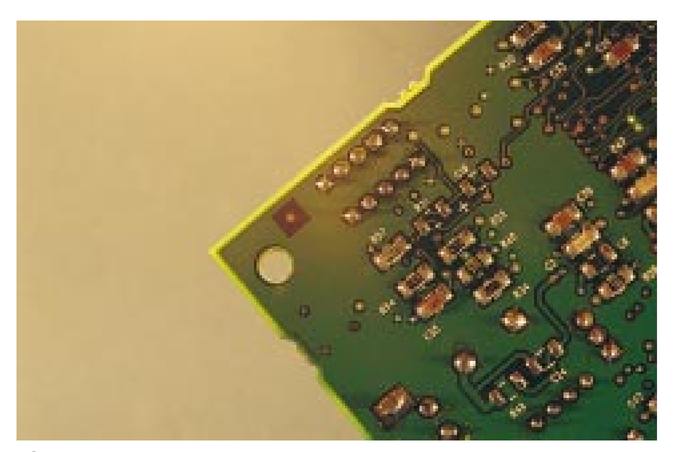




Figure 10-20

Target - Class 1,2,3

- No haloing or edge delamination.

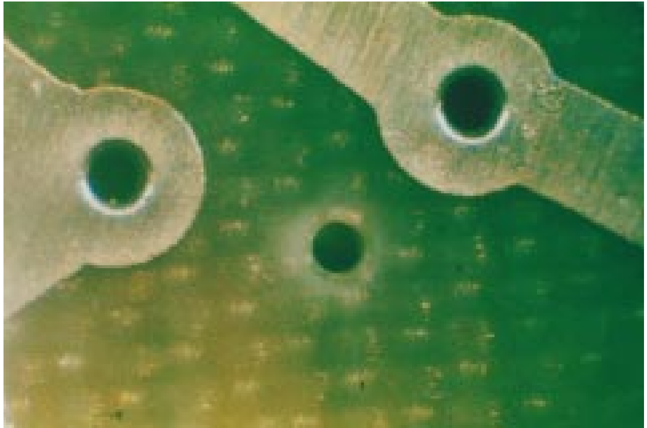


Figure 10-21

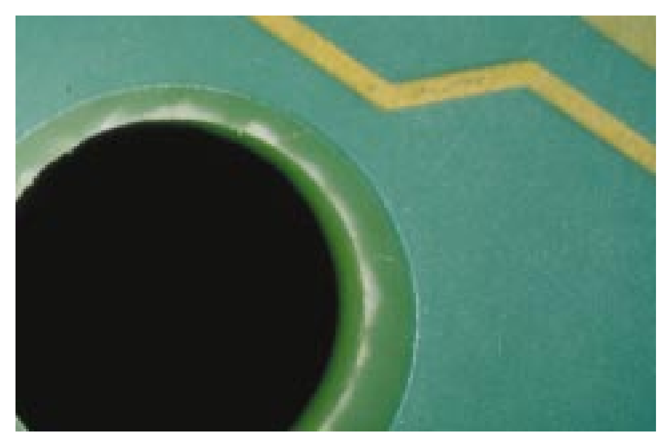


Figure 10-22

Acceptable - Class 1,2,3

- Penetration of haloing or edge delamination does not reduce edge spacing more than 50% of that specified by drawing note or equivalent documentation. If none is specified, the distance from haloing or edge delamination to conductors is greater than 0.127 mm [0.005 in]. The maximum haloing or edge delamination is not greater than 2.5 mm [0.0984 in].

10.2.4 Laminate Conditions – Haloing and Edge Delamination (cont.)

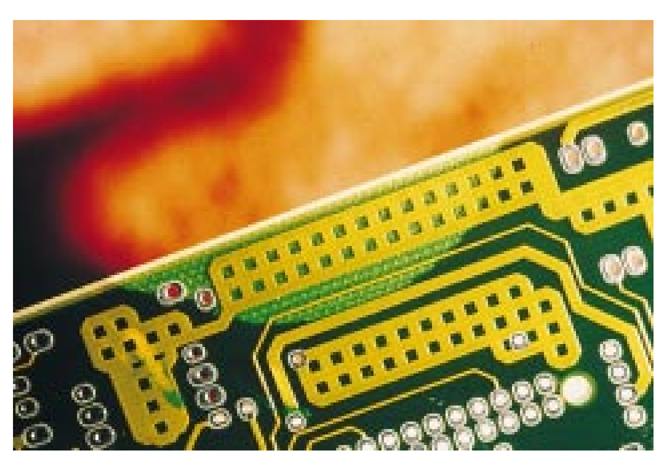


Figure 10-23



Figure 10-24

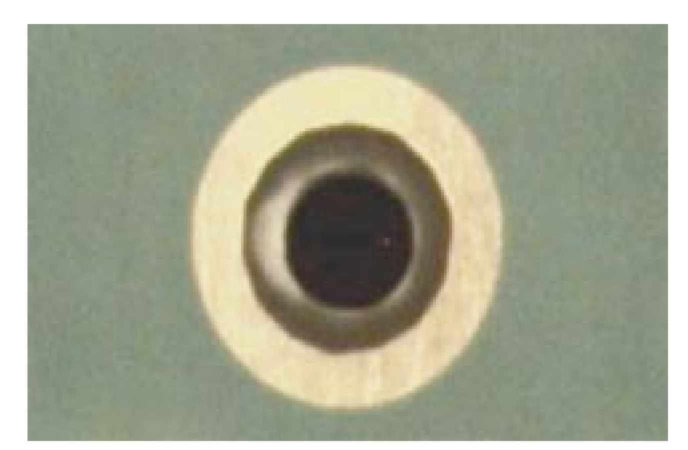


Figure 10-25

Defect - Class 1,2,3

- Penetration of haloing or edge delamination, at board edges, holes or cut-outs, reduces the unaffected distance from the edge to the closest conductive pattern by more than 50% of that specified, or to less than 0.127 mm [0.005 in] or extends more than 2.5 mm [0.0984 in] from the edge, whichever is less.

10.2.5 Laminate Conditions – Pink Ring

There is no known evidence that pink ring affects functionality. The presence of excessive pink ring may be considered an indicator of process or design variation but is not a cause for rejection. The focus of concern is the quality of the lamination bond.

10.2.6 Burns



Figure 10-26



Figure 10-27

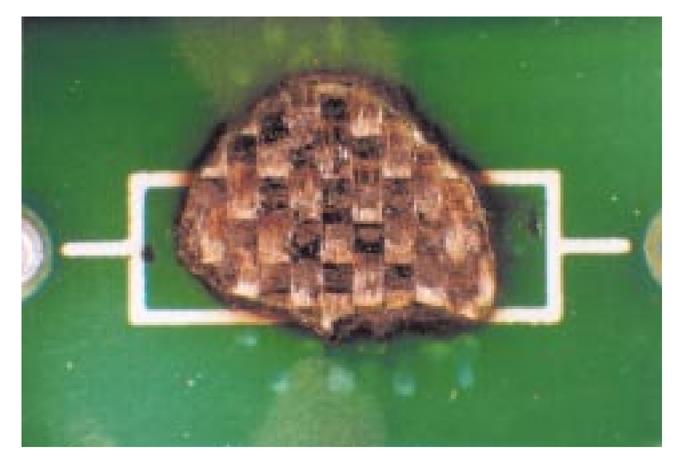


Figure 10-28

Defect - Class 1,2,3

- Burns which physically damage surface or the assembly.

10.2.7 Laminate Conditions – Bow and Twist

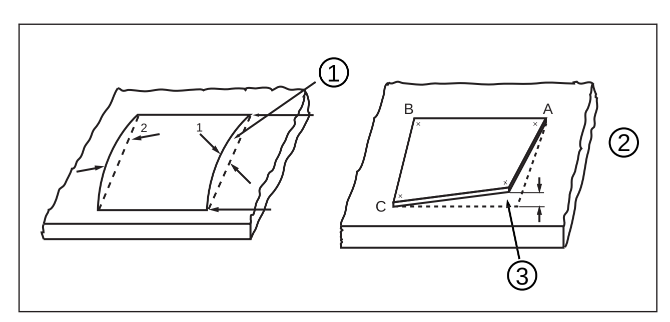


Figure 10-29
1. **Bow**
2. **Points A, B and C are touching base**
3. **Twist**

Acceptable - Class 1,2,3

- Bow and twist does not cause damage during post solder assembly operations or end use. Consider ‘‘Form, Fit and Function’’ and product reliability.

Defect - Class 1,2,3

- Bow and twists causes damage during post solder assembly operations or end use.

Note: Bow and twist after solder should not exceed 1.5% for through-hole and 0.75% for surface mount printed board applications (See IPC-TM-650, 2.4.22).

10.2.8 Laminate Conditions – Flexible and Rigid-Flex Printed Circuitry

10.2.8.1 Laminate Conditions – Flexible and Rigid-Flex Printed Circuitry – Nicks and Tears

The trimmed edge of the flexible printed circuit or the flexible section rigid-flex printed circuit is free of burrs, nicks, delamination, or tears in excess of that allowed in the procurement documentation. Minimum edge to conductor spacing needs to be specified in the procurement documentation.

The deformation of a stiffener board should conform to the master drawing or the individual specification.

Note: For SMT or through-hole component mounting, placement, soldering, cleanliness criteria on flex assemblies, etc., follow the applicable sections of this standard.

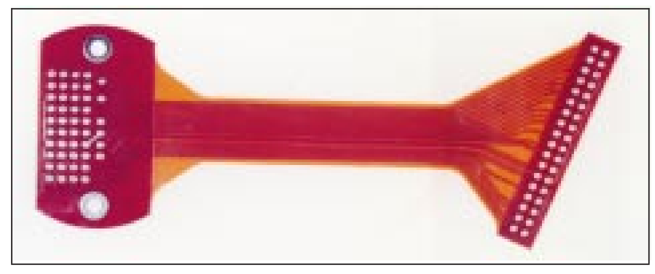


Figure 10-30

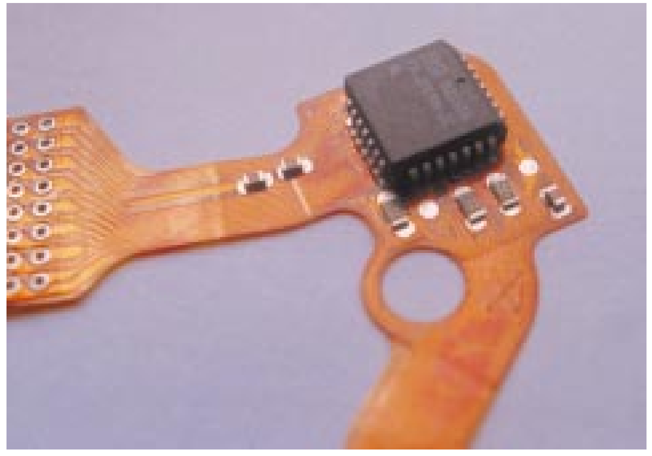


Figure 10-31

Target - Class 1,2,3

- Free of nicks and tears. Minimum edge to conductor spacing maintained.
- The trimmed edge of the flexible printed circuit or the flexible section of finished rigid-flex printed circuit is free of burrs, nicks, delamination, and tears.

10.2.8.1 Laminate Conditions – Flexible and Rigid-Flex Printed Circuitry – Nicks and Tears (cont.)

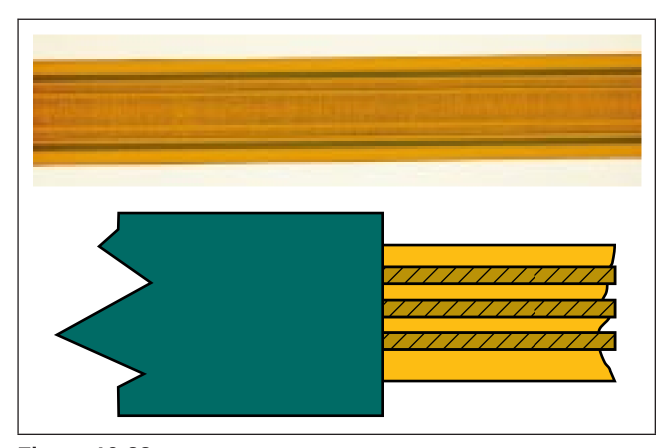


Figure 10-32

Acceptable - Class 1,2,3

- No nicks or tears in excess of that specified in the procurement documentation.
- Edge to conductor spacing of the flexible portion is within requirements specified on the procurement documentation.
- Nicks or haloing along the edges of the flexible printed circuit, cutouts, and unsupported holes, providing the penetration does not exceed 50% of the distance from the edge to the nearest conductor or 2.5 mm [0.0984 in], whichever is less.
- The area of blister or delamination between flex circuitry and a stiffener board does not exceed 20% of the joined area provided the thickness of the blister does not exceed the thickness limit of the entire board.

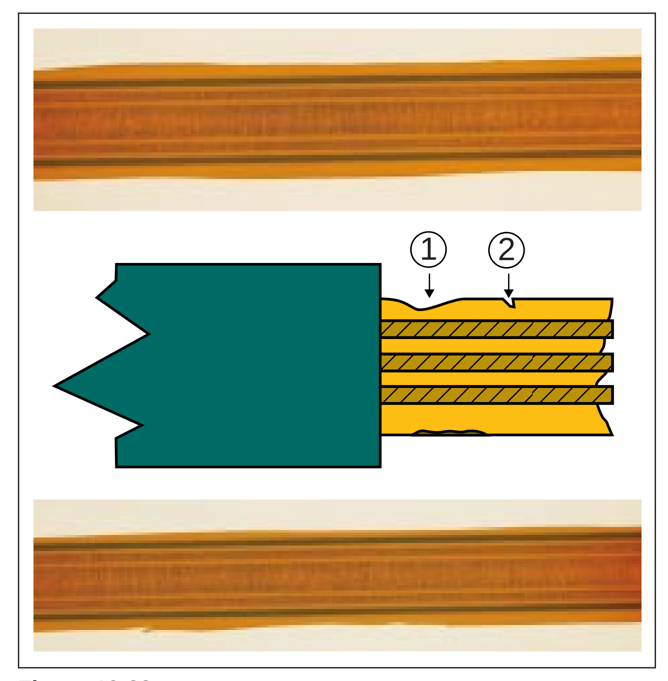


Figure 10-33
1. Nick 2. Tear

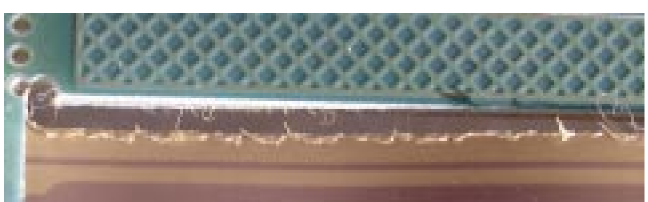


Figure 10-34

Defect - Class 1,2,3

- Nicks, tears, haloing or imperfections more than 50% of the distance from the edge to the nearest conductor or 2.5 mm [0. 098 in], whichever is less, or in excess of that specified in the procurement documentation.
- Edge to conductor spacing does not comply with specified requirements.
- The area of blister or delamination between flex circuitry and a stiffener board exceeds 20% of the joined area.

10.2.8.2 Laminate Conditions – Flexible and Rigid – Flex Printed Circuitry – Stiffener Board Delamination

Sometimes delamination takes place between flex circuitry and the edge of a stiffener board during reflow, cleaning steps, etc. of assembly process.

Acceptable - Class 1,2,3

- The distance from stiffener board edge in the straight section is 0.5 mm [0.0197 in] or less.
- The distance from stiffener board edge in the bend section is 0.3 mm or less.

Defect - Class 1,2,3

- The distance from stiffener board edge in the straight section exceeds 0.5 mm [0.0197 in].
- The distance from stiffener board edge in the bend section exceeds 0.3 mm [0.012 in].

10.2.8.3 Laminate Conditions – Flexible and Rigid – Flex Printed Circuitry – Discoloration

Acceptable - Class 1,2,3

- A discolored conductor meets the requirements of dielectric withstanding voltage, flexural fatigue resistance, bending resistance, and solder temperature resistance, after being subjected to the moisture resistance test of 40°C, 40% relative humidity, 96 hours.

Acceptable - Class 1

- Minimum discoloration.

Defect - Class 1,2,3

- A discolored conductor does not meet the requirements of dielectric withstanding voltage, flexural fatigue resistance, bending resistance, or solder temperature resistance, after being subjected to the moisture resistance test of 40°C, 40% relative humidity, 96 hours.

10.2.8.4 Laminate Conditions – Flexible and Rigid – Flex Printed Circuitry – Solder Wicking

Additional illustrations are provided in IPC-A-600G, Clause 4.1.7.

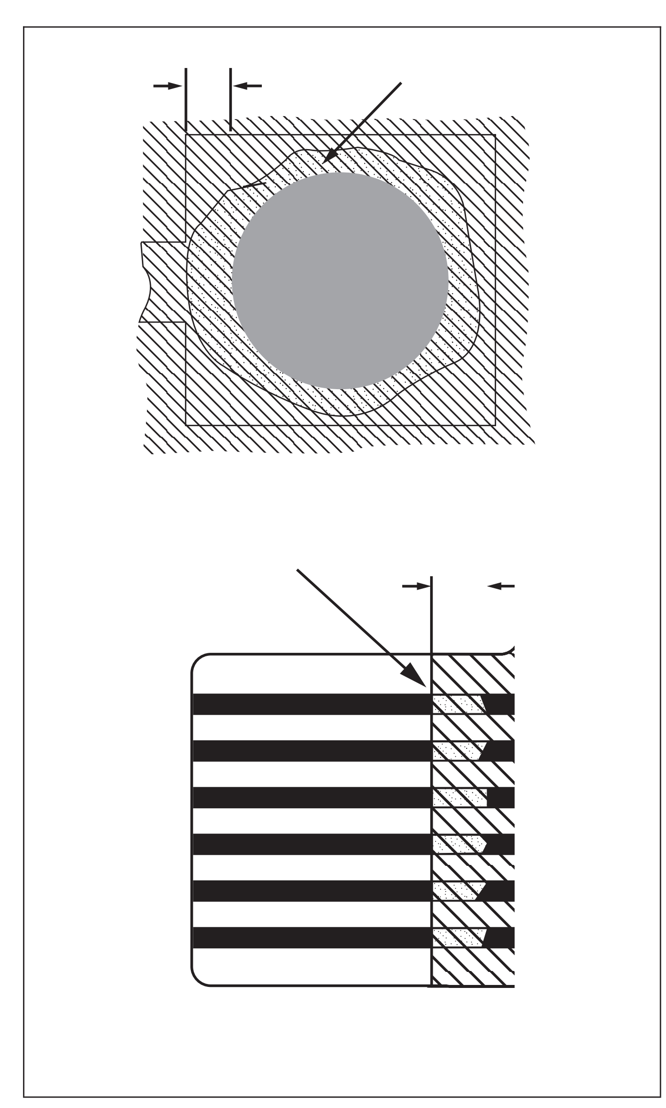


Figure 10-35

Target - Class 1,2,3

- Solder or plating on land covers all exposed metal and stops at coverlayer.
- Solder wicking or plating migration does not extend into the bend or flex transition area.

Acceptable - Class 1

- As agreed upon between user and supplier.
- Solder wicking or plating migration does not extend into the bend or flex transition area.
- Meets conductor spacing requirements.

Acceptable - Class 2

- Solder wicking/plating migration does not extend under coverlayer more than 0.5 mm [0.020 in].
- Solder wicking or plating migration does not extend into the bend or flex transition area.
- Meets conductor spacing requirements.

Acceptable - Class 3

- Solder wicking/plating migration does not extend under coverlayer more than 0.3 mm [0.012 in].
- Solder wicking or plating migration does not extend into the bend or flex transition area.
- Meets conductor spacing requirements.

Defect - Class 1,2,3

- Defects exceed above criteria.

10.2.9 Laminate Conditions – Conductors/Lands

10.2.9.1 Laminate Conditions – Conductors/ Lands – Reduction in Cross-Sectional Area

IPC-6010 (Series) provides the requirements for conductor width and thickness reduction.

Conductor Imperfections - The physical geometry of a conductor is defined by its width x thickness x length. Any combination of defects does not reduce the equivalent cross-sectional area (width x thickness) of the conductor by more than 20% of the minimum value (minimum thickness x minimum width) for Class 2 and 3, and 30% of the minimum value for Class 1.

Conductor Width Reduction - Allowable reduction of the conductor width (specified or derived) due to isolated defects (i.e., edge roughness, nicks, pinholes and scratches) does not exceed 20% of the minimum printed conductor width for Class 2 and 3, and 30% of the minimum printed conductor width for Class 1.

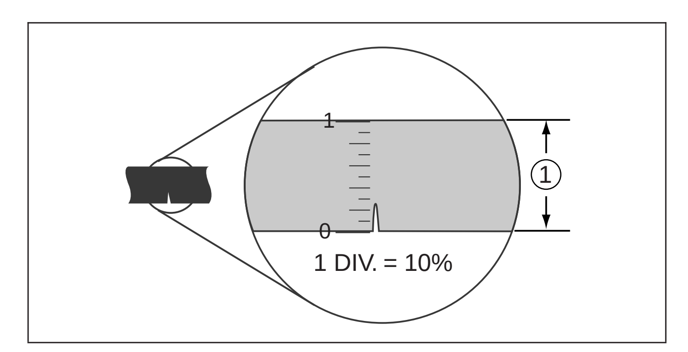


Figure 10-36
1. Minimum conductor width

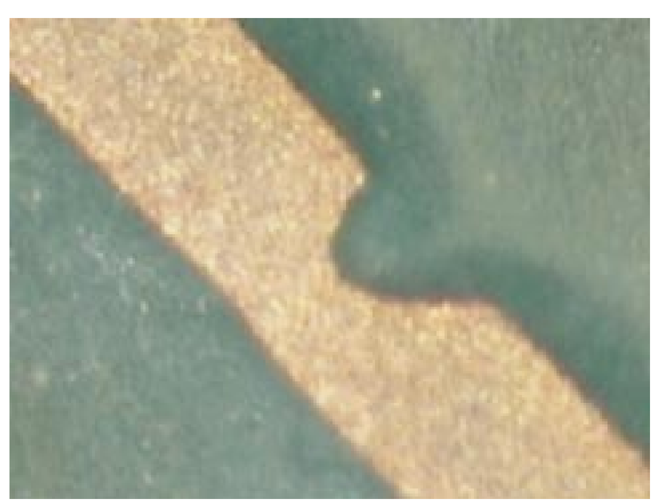


Figure 10-37

Defect - Class 1

- Reduction in minimum width of printed conductors by more than 30%.
- Reduction in minimum printed conductor width or length of lands by more than 30%.

Defect - Class 2, 3

- Reduction in minimum width of printed conductors by more than 20%.
- Reduction in width or length of lands by more than 20%.

10.2.9.2 Laminate Conditions – Conductors/Lands – Lifted Pads/Lands

When the outer, lower edge of land areas are lifted or separated more than the thickness (height) or the land.

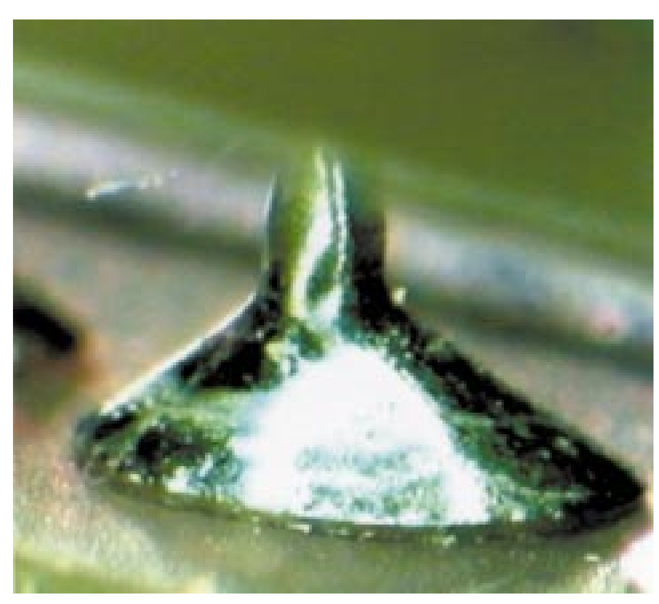


Figure 10-38

Target - Class 1,2,3

- No separation between conductor, pad or land and the laminate surface.



Figure 10-39

Process Indicator - Class 1,2,3

- Separation between outer edge of conductor, pad or land and laminate surface is less than one pad thickness.

Note: Lifted and/or separated land area(s) is typically a result of the soldering process that warrants immediate investigation to determine root cause. Efforts to eliminate and/or prevent this condition should be made.

10.2.9.2 Laminate Conditions – Conductors/Lands – Lifted Pads/Lands (cont.)

Defect - Class 1,2,3

- Separation between conductor or land and laminate surface is greater than one pad thickness.

Defect - Class 3

- Any lifting of a land if there is a via in the land.

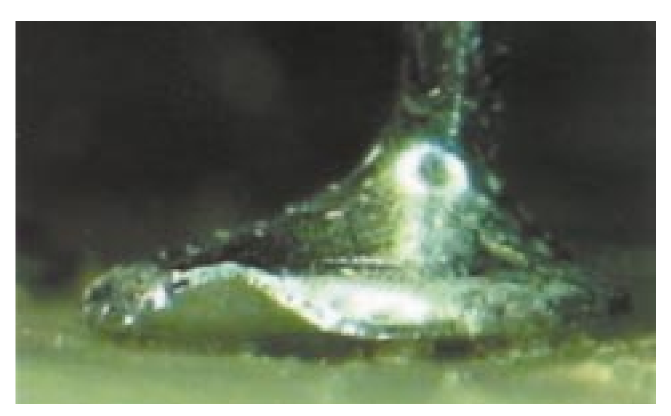


Figure 10-40

Figure 10-41



Figure 10-42

10.2.9.3 Laminate Conditions – Conductors/Lands – Mechanical Damage

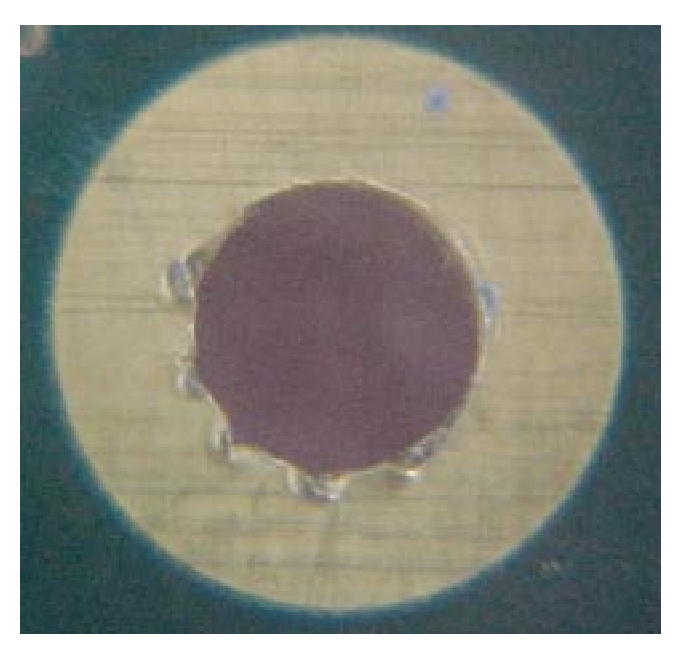


Figure 10-43

Defect - Class 1,2,3

- Damage to conductors or lands.

10.3 Marking

Marking Acceptability Requirements

This section covers acceptability criteria for marking of printed boards and other electronic assemblies.

Marking provides both product identification and traceability. It aids in assembly, in-process control, and field servicing. The methods and materials used in marking must serve the intended purposes and must be readable, durable, and compatible with the manufacturing processes and should remain legible through the life of the product.

Examples of the markings addressed by this section include the following:

a. Electronic Assemblies:
- company logo
- board fabrication part numbers and revision level
- assembly part number, group number, and revision level
- component legends including reference designators and polarity indicators (only applies prior to assembly processing/cleaning)
- certain inspection and test traceability indicators
- U.S. and other relevant regulatory agencies/certifications
- unique individual serial number
- date code

b. Modules and/or Higher Level Assemblies:
- company logo
- product identification numbers, e.g., drawing number, revision and serial number
- installation and user information
- relevant regulatory agencies' certification labels

The fabrication and assembly drawings are the controlling documents for the locations and types of markings. Marking criteria specified in the drawings will take precedence over these criteria.

In general, additive markings over metal surfaces are not recommended. Markings which serve as aids to assembly and inspection need not be visible after the components are mounted.

Assembly marking (part numbers, serial numbers) need to remain legible (capable of being read and understood as defined by the requirements of this standard) after all tests, cleaning and other processes to which the item is subjected.

Component markings, reference designators and polarity indicators should be legible and components should be mounted in such a manner that markings are visible. However, unless otherwise required, it is an acceptable condition if these markings are removed or damaged during normal cleaning or processing. Where component marking visibility and legibility is desired, the requirement needs to be stated in procurement documentation.

Markings are not deliberately altered, obliterated, or removed by the manufacturer unless required by the assembly drawing(s)/documentation. Additional markings such as labels added during the manufacturing process should not obscure the original supplier's markings. Permanent labels need to comply with the adhesion requirements of 10.3.5.3. Components and fabricated parts need not be mechanically installed so that the reference designations are visible when installed.

Acceptance of the marking is based on using the unaided eye. Magnification, if used, is limited to 4X.

10.3.1 Marking – Etched (Including Hand Printing)

Hand printing may include marking with indelible pen or mechanical etcher.

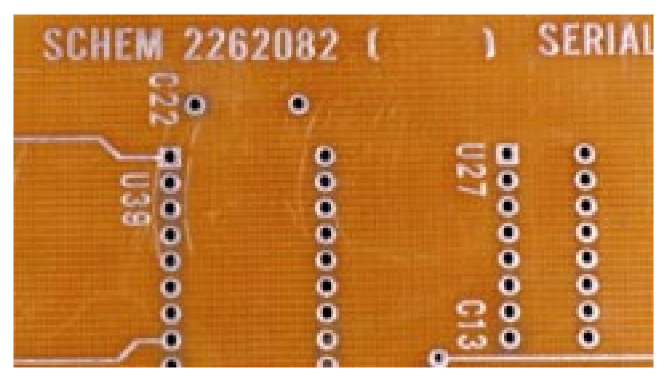


Figure 10-44

Target - Class 1,2,3

- Each number or letter is complete, i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible.
- Lines forming the character are sharply defined and uniform in width.
- Minimum spacing requirements between active conductors have also been maintained between etched symbolization and active conductors.



Figure 10-45

Acceptable - Class 1,2,3

- Edges of the lines forming a character may be slightly irregular. Open areas within characters may be filled providing the characters are legible and cannot be confused with another letter or number.
- Width of the lines forming a character may be reduced by up to 50% providing they remain legible.
- Lines of a number or letter may be broken provided the breaks do not make the marking illegible.



Figure 10-46

Acceptable - Class 1
Process Indicator - Class 2,3

- Legends are irregularly formed but the general intent of the legend or marking is discernible.

Defect - Class 1,2,3

- Missing or illegible characters in the markings.
- Marking violates the minimum electrical clearance limits.
- Solder bridging within or between characters or characters/conductors preventing character identification.
- Lines forming a character are missing or broken to the extent that the character is not legible or is likely to be confused with another character.

10.3.2 Marking – Screened

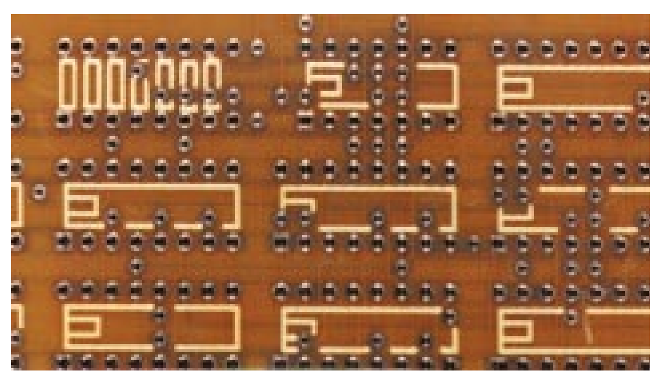


Figure 10-47

Target - Class 1,2,3

- Each number or letter is complete i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible. Lines forming the character are sharply defined and uniform in width.
- Ink forming the markings is uniform, i.e., there are no thin spots or excessive build-ups.
- The open areas within characters are not filled (applies to numbers 0, 6, 8, 9, and letters A, B, D, O, P, Q, R).
- There are no double images.
- Ink is confined to the lines of the character, i.e., there are no smeared characters and the build-up of material outside the characters is held to a minimum.
- Ink markings may touch or cross over conductors but are no closer than tangent to a land.

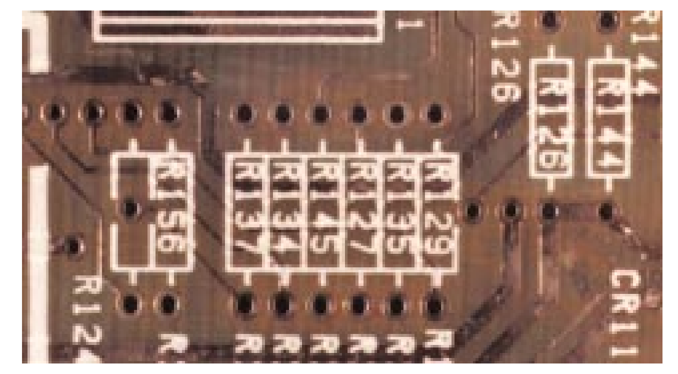


Figure 10-48

Acceptable - Class 1,2,3

- Ink may be built up outside the line of a character providing the character is legible.
- Marking ink on the land does not interfere with soldering requirements.

Acceptable - Class 1
Process Indicator - Class 2,3

- Lines of a number or letter may be broken (or the ink thin over a portion of the character) providing the breaks do not make the markings illegible.

Process Indicator - Class 2,3

- The open areas within characters may be filled providing the characters are legible, i.e., cannot be confused with another letter or number.

Defect - Class 1,2,3

- Marking ink is present on the land interfering with the solder requirements of Tables 7-3, 7-6 or 7-7 or with the surface mount soldering requirements of Section 8.

10.3.2 Marking – Screened (cont.)

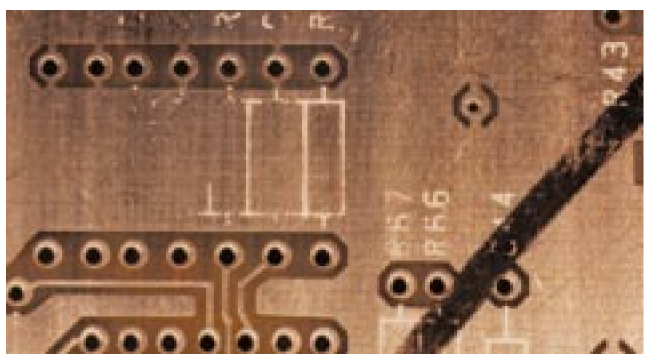


Figure 10-49

Acceptable - Class 1
Process Indicator - Class 2,3

- Marking that is smeared or blurred but is still legible.
- Double images are legible.

Defect - Class 1,2,3

- Missing or illegible markings or reference designators for component location, or component outlines.
- Missing or illegible characters in the markings.
- Open areas of characters are filled and are not legible, or are likely to be confused with another number or letter.
- Lines forming a character are missing, broken or smeared to the extent that the character is not legible or is likely to be confused with another character.

10.3.3 Marking – Stamped



Figure 10-50

Target - Class 1,2,3

- Each number or letter is complete, i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible.
- Lines forming the character are sharply defined and uniform in width.
- Ink forming the markings is uniform, i.e., there are no thin spots or excessive build-ups.
- The open areas within characters are not filled (applies to numbers 0, 6, 8, 9 and letters A, B, D, O, P, Q, R).
- There are no double images.
- Ink is confined to the lines of the character, i.e., there are no smeared characters and the build-up of material outside the characters is held to a minimum.
- Ink markings may touch or cross over conductors but are no closer than tangent to a solderable land.

10.3.3 Marking – Stamped (cont.)



Figure 10-51

Acceptable - Class 1,2,3

- Ink may be built up outside the line of a character providing the character is legible.
- Marking ink is present on the land (see soldering requirements of Tables 7-3, 7-6 or 7-7 or the surface mount soldering requirements of Section 8).

Acceptable - Class 1
Process Indicator - Class 2,3

- Lines of a number or letter may be broken (or the ink thin over a portion of the character) providing the breaks do not make the markings illegible.
- The open areas within characters may be filled providing the characters are legible, i.e., cannot be confused with another letter or number.

Defect - Class 1,2,3

- Marking ink is present on the land interfering with the solder requirements of Tables 7-3, 7-6 or 7-7 or with the surface mount soldering requirements of Section 8.



Figure 10-52

Acceptable - Class 1
Process Indicator - Class 2,3

- Marking that has been smeared or blurred but is still legible.
- Double stamped markings are acceptable provided the general intent can be determined.
- Missing or smeared marking does not exceed 10% of the character and the character is still legible.

Defect - Class 1,2,3

- Missing or illegible characters in the markings.
- Open areas of characters are filled and are not legible, or are likely to be confused with another number or letter.
- Lines forming a character are missing, broken or smeared to the extent that the character is not legible or is likely to be confused with another character.

10.3.4 Marking – Laser



Figure 10-53

Target - Class 1,2,3

- Each number or letter is complete, and legible, i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible.
- Lines forming the character are sharply defined and uniform in width.
- Marking forming the characters is uniform, i.e., there are no thick or thin spots.
- The open areas within characters are not filled (applies to numbers 0, 6, 8, 9 and A, B, D, O, P, Q, R).
- Marking is confined to the lines of the character, i.e., do not touch or cross over solderable surfaces.
- The depth of the marking does not adversely affect the function of the part.
- There is no exposed copper when marking on the ground plane of printed circuit boards.
- There is no delamination when marking on the printed circuit board dielectric.

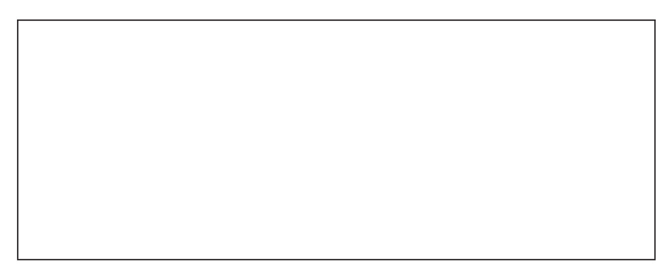


Figure 10-54 (deleted)

Acceptable - Class 1,2,3

- Marking may be built up outside the line of a character providing the character is legible.

10.3.4 Marking - Laser (cont.)



Figure 10-55

Acceptable - Class 1
Process Indicator - Class 2,3

- Multiple image is still legible.
- Missing marking is not more than 10% of the character.
- Lines of a number or letter may be broken (or thin over a portion of the character).

Defect - Class 1,2,3

- Missing or illegible characters in the markings.
- Open areas of characters are filled and are not legible, or are likely to be confused with another number or letter.
- Lines forming a character are missing, broken or smeared to the extent that the character is not legible or is likely to be confused with another character.
- The depth of the marking adversely affects the function of the part.
- Marking exposes copper on the ground plane of printed circuit boards.
- Delamination on the printed circuit board dielectric from marking.
- Markings touch or cross over solderable surfaces.

10.3.5 Marking – Labels

Permanent labels are commonly used to attach bar code data, but may include text. Readability, adhesion and damage criteria apply to all permanent labels.

10.3.5.1 Marking – Labels – Bar Coding

Bar coding has gained wide acceptance as a method of product identification, process control and traceability because of ease and accuracy of data collection and processing. Bar code labels are available which occupy small areas (some can be attached to the thickness edge of the PCB) and can withstand the normal wave soldering and cleaning operations. Bar coding can also be laser scribed directly on to the base material. Acceptability requirements are the same as other types of markings except for legibility where machine readability replaces human readability.

10.3.5.2 Marking – Labels – Readability



Figure 10-56

Target - Class 1,2,3

- No spots or voids on printed surfaces.

Acceptable - Class 1,2,3

- Spots or voids on printed surfaces of bar codes are permissible provided that either:
  - Bar code can be read successfully with three (3) or fewer attempts using a wand type scanner.
  - The bar code can be read successfully with two (2) or fewer attempts using a laser scanner.
- Text is legible.

Defect - Class 1,2,3

- Bar code cannot be successfully read within three (3) attempts using a wand type scanner.
- Bar code cannot be read successfully within two (2) attempts using a laser scanner.
- Missing or illegible characters in the markings.

10.3.5.3 Marking – Labels – Adhesion and Damage

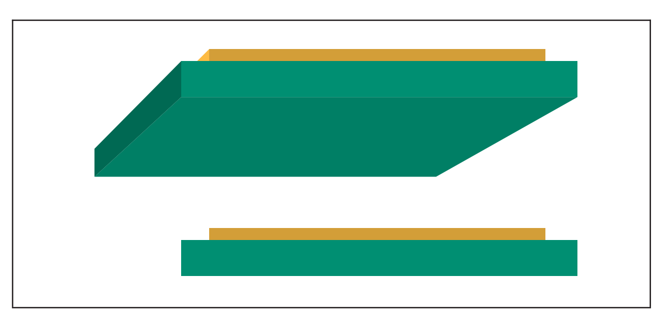


Figure 10-57

Target - Class 1,2,3

• Adhesion is complete, shows no sign of damage or peeling.

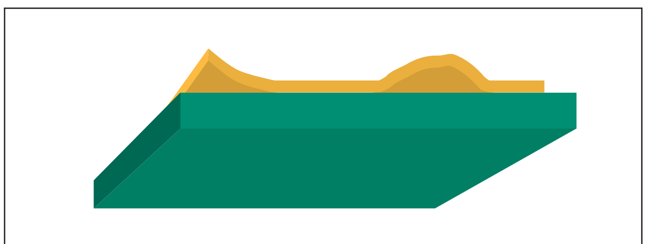


Figure 10-58

Defect - Class 1,2,3

• More than 10% of the label area is peeling.

• Missing labels.

• Label wrinkle affects readability.

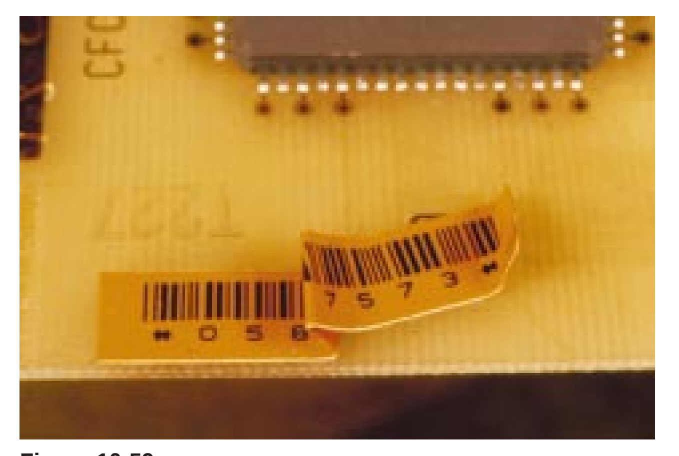


Figure 10-59

10.3.5.4 Marking – Labels – Position

Acceptable - Class 1,2,3

• Label is applied in the required position.

Defect - Class 1,2,3

• Label is not applied in the required position.

10.4 Cleanliness

Cleanliness Acceptability Requirements

This section covers acceptability requirements for cleanliness of assemblies. The following are examples of the more common contaminants found on printed board assemblies. Others may appear, however, and all abnormal conditions should be evaluated. The conditions represented in this section apply to both primary and secondary sides of the assemblies. See IPC- CH-65 for additional cleaning information.

Contaminant is not only to be judged on cosmetic or functional attributes, but as a warning that something in the cleaning system is not working properly.

Testing a contaminant for functional effects is to be performed under conditions of the expected working environment for the equipment.

Every production facility should have a standard based on how much of each type of contaminant can be tolerated. The more cleaning that has to be done, the more expensive the assembly. Testing with ionic extract devices based on J-STD-001, insulation resistance tests under environmental conditions and other electrical parameter tests as described in IPC-TM-650 are recommended for setting a facility standard.

See 1.8 for inspection magnification requirements.

10.4.1 Flux Residues

The flux classification (see J-STD-004) and assembly process, i.e., no-clean, clean, etc., need to be identified and considered when applying these criteria.



Figure 10-60

Target - Class 1,2,3

- Clean, no discernible residue.

Acceptable - Class 1,2,3

- No discernible residue from cleanable fluxes is allowed.
- Flux residues from no-clean processes may be allowed.



Figure 10-61

Defect - Class 1,2,3

- Discernible residue from cleanable fluxes, or any activated flux residues on electrical contact surfaces.

Note 1. Class 1 may be acceptable after qualification testing. Check also for flux entrapment in and under components.

Note 2. Flux residue activity is defined in J-STD-001 and J-STD-004.

Note 3. Processes designated ‘‘no-clean’’ need to comply with end-product cleanliness requirements.

10.4.2 Particulate Matter



Figure 10-62

Target - Class 1,2,3

- Clean.




Figure 10-63

Defect - Class 1,2,3

- Dirt and particulate matter on assembly, e.g., dirt, lint, dross, metallic particles, etc., see 5.2.6.1 for exceptions.

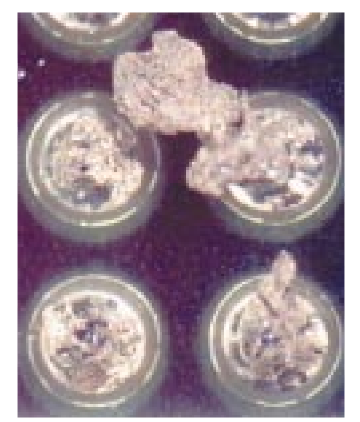


Figure 10-64

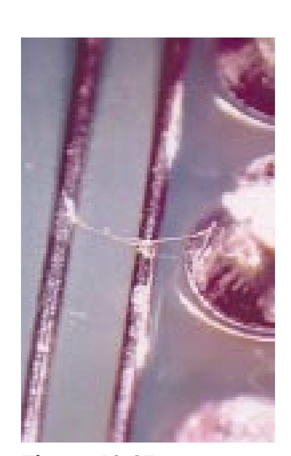


Figure 10-65

10.4.3 Chlorides, Carbonates and White Residues

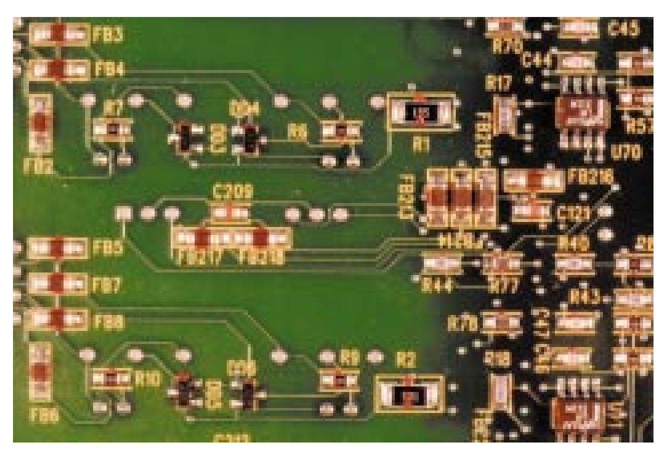


Figure 10-66

Target - Class 1,2,3

• No discernible residue.

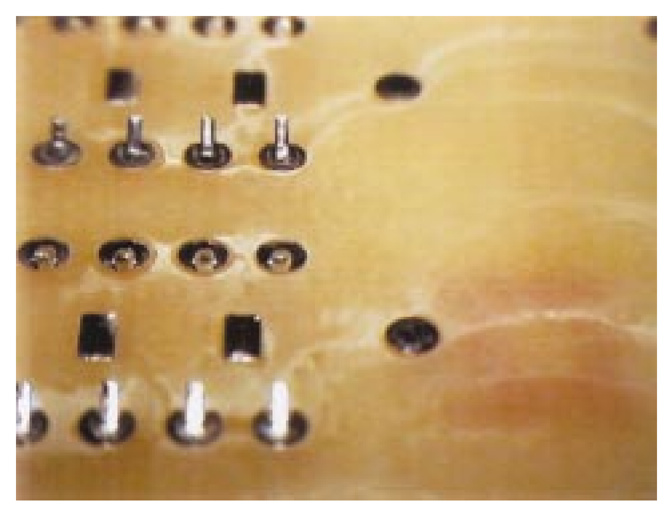


Figure 10-67

Defect - Class 1,2,3

• White residue on PCB surface.

• White residues on or around the soldered termination.

• Metallic areas exhibit crystalline white deposit.

Note: White residues resulting from no-clean or other processes are acceptable provided the residues from chemistries used have been qualified and documented as benign. See 10.4.4.

10.4.3 Chlorides, Carbonates and White Residues (cont.)

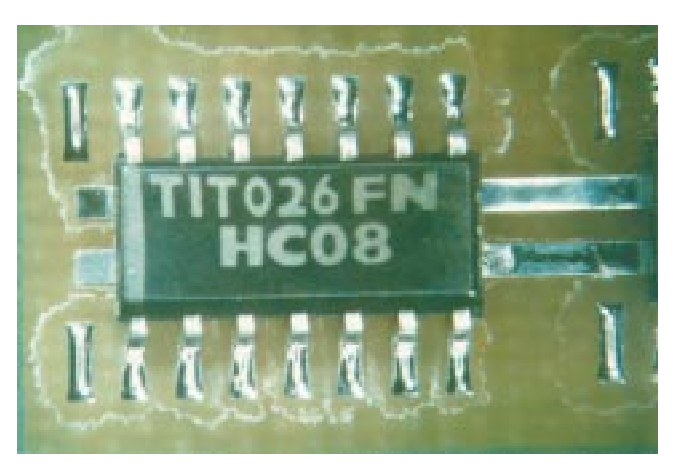


Figure 10-68



Figure 10-69

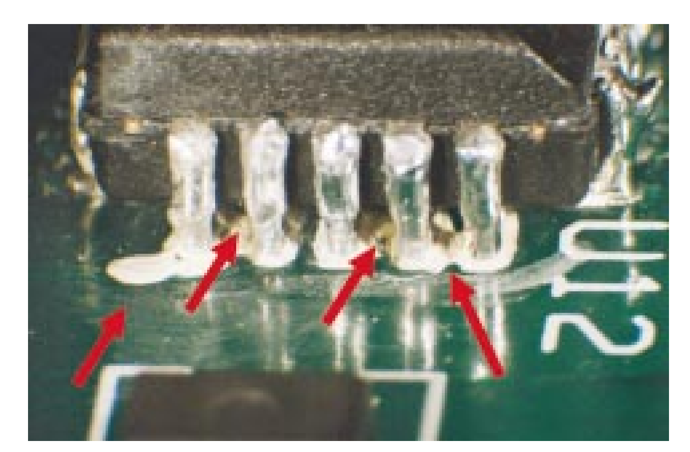


Figure 10-70

10.4.4 Flux Residues – No-Clean Process – Appearance

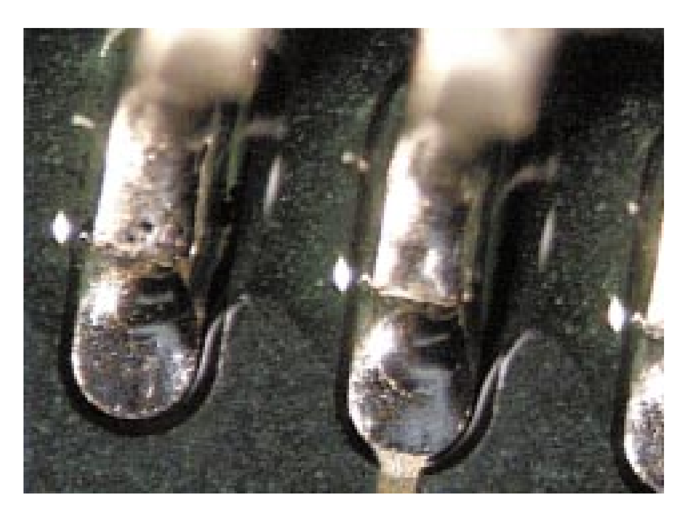


Figure 10-71

Acceptable - Class 1,2,3

- Flux residue on, around, or bridging between noncommon lands, component leads and conductors.
- Flux residue does not inhibit visual inspection.
- Flux residue does not inhibit access to test points of the assembly.

Defect - Class 2,3

- Flux residue inhibits visual inspection.
- Flux residue inhibits access to test points.

Note 1. There is no defect for discoloration of OSP coated assemblies that come in contact with flux residues from no-clean process.

Note 2. Residue appearance may vary depending upon flux characteristics and solder processes.

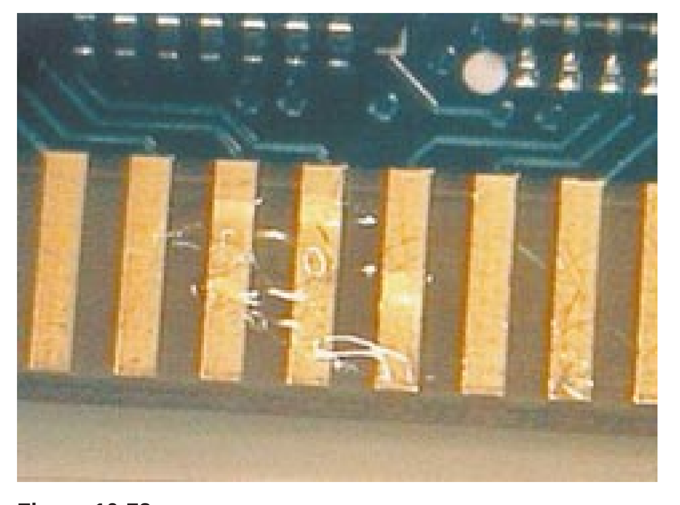


Figure 10-72

Acceptable - Class 1
Process Indicator - Class 2
Defect - Class 3

- Finger prints in no-clean residue.

Defect - Class 1,2,3

- Wet, tacky, or excessive flux residues that may spread onto other surfaces.
- No-clean flux residue on any electrical mating surface that inhibits electrical connection.

10.4.5 Surface Appearance

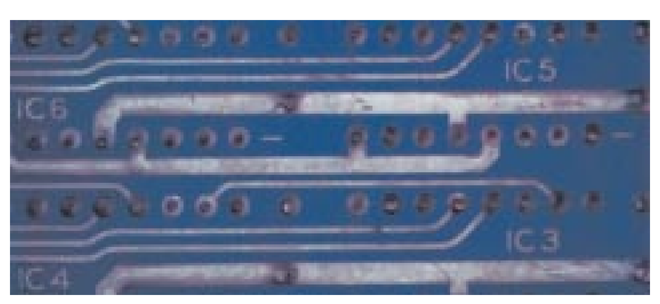


Figure 10-73

Acceptable - Class 1,2,3

- Slight dulling of clean metallic surfaces.

10.4.5 Surface Appearance (cont.)


Figure 10-74

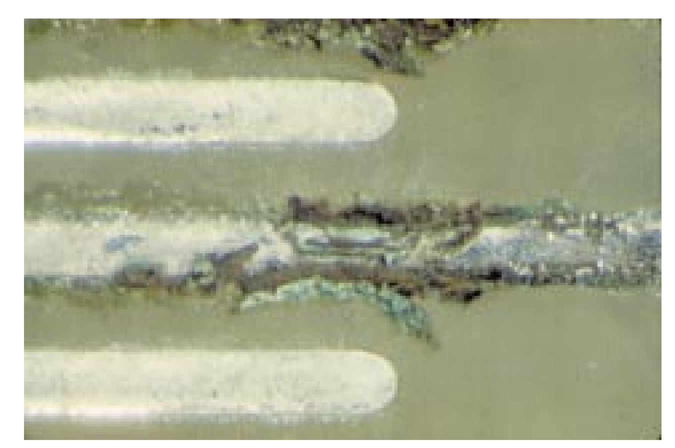

Figure 10-75


Figure 10-76

Defect - Class 1,2,3

- Colored residues or rusty appearance on metallic surfaces or hardware.
- Evidence of corrosion.

10.5 Coatings

Coatings Acceptability Requirements

This section covers the acceptability requirements for conformal coatings and solder resist coatings on electronic assemblies.

Additional information on solder resist is available in IPC-SM-840. Additional information on conformal coating is available in IPC-CC-830 and IPC-HDBK-830.

10.5.1 Solder Resist Coating

Solder Resist (Mask) - A heat-resisting coating material applied to selected areas to prevent the deposition of solder upon those areas during subsequent soldering. Solder resist material may be applied as a liquid or a dry film. Both types meet the requirements of this guideline.

Although not rated for dielectric strength, and therefore not satisfying the definition of an ‘‘insulator or insulating material,’’ some solder resist formulations provide limited insulation and are commonly used as surface insulation where high voltages are not a consideration.

In addition, solder resist is useful in preventing PCB surface damage during assembly operations.

Tape Test - The tape test referenced in this section is IPC-TM-650, Test Method 2.4.28.1. All loose and nonadhering material needs to be removed.

See IPC-A-600.

10.5.1.1 Solder Resist Coating – Wrinkling/Cracking

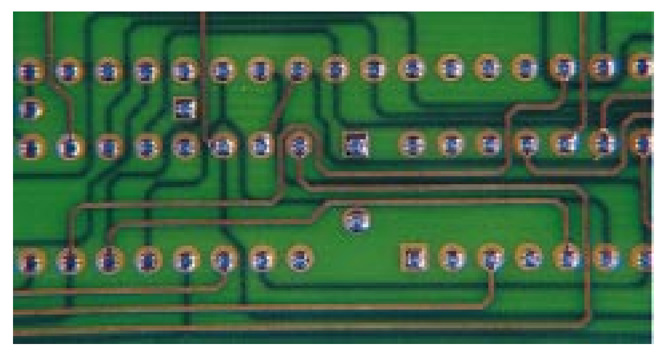


Figure 10-77

Target - Class 1,2,3

- There is no evidence of cracking of the solder resist after the soldering and cleaning operations.

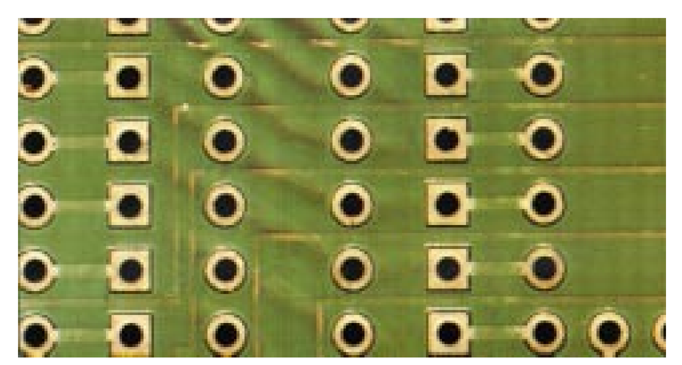


Figure 10-78

Acceptable - Class 1,2,3

- Minor wrinkling is located in an area that does not bridge between conductive patterns and meets the adhesion tape pull test, IPC-TM-650, 2.4.28.1.

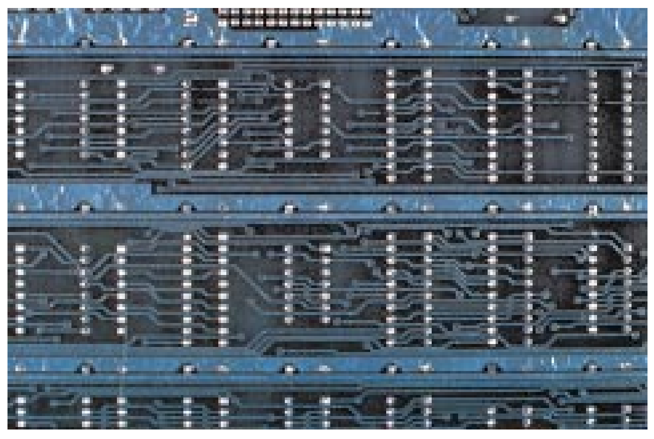


Figure 10-79

Acceptable - Class 1,2,3

- Wrinkling of the solder resist film over area of reflowed solder is acceptable providing there is no evidence of breaking, lifting or degradation of the film. Adhesion of wrinkled areas can be verified using a tape pull test.

10.5.1.1 Solder Resist Coating – Wrinkling/Cracking (cont.)

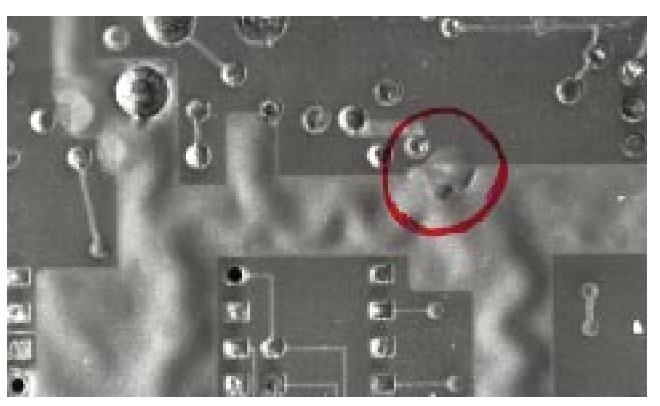


Figure 10-80

Acceptable - Class 1,2
Defect - Class 3

• Cracking of solder resist.

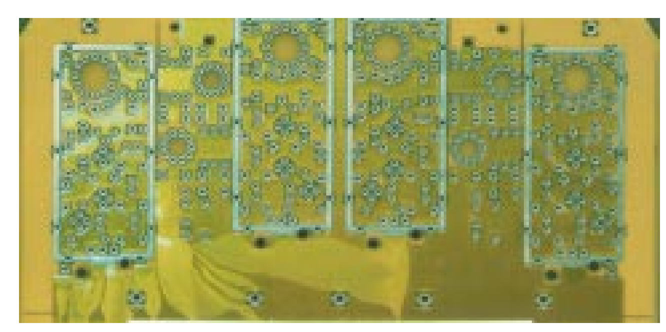


Figure 10-81

Defect - Class 1,2,3

• Loose particles cannot be completely removed and will affect the operation of the assembly.

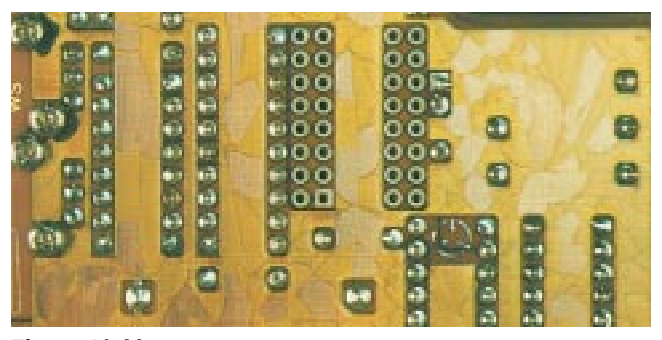


Figure 10-82

10.5.1.2 Solder Resist Coating – Voids and Blisters

During solder assembly operation, the resist prevents solder bridging. Blistering and loose particles of solder resist material are acceptable after the completion of the assembly provided they will not affect other functions in the assembly.

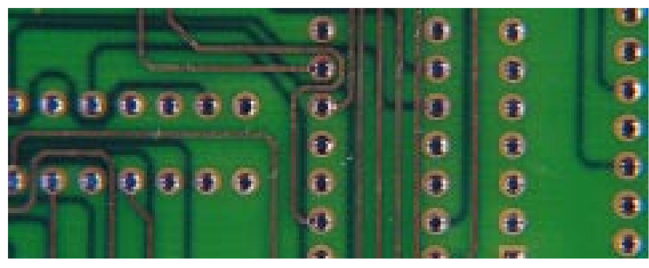


Figure 10-83

Target - Class 1,2,3

- No blisters, scratches, voids or wrinkling evident under solder resist after soldering and cleaning operations.

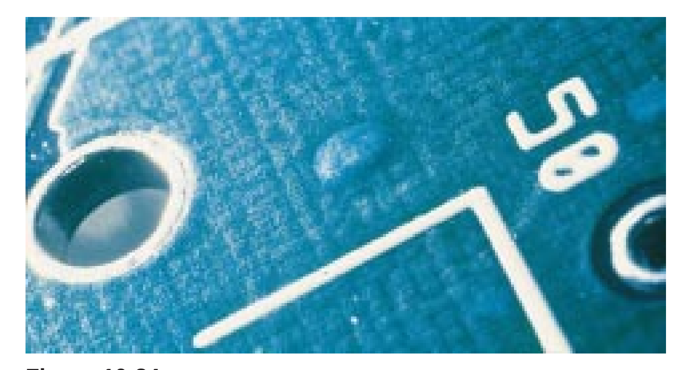


Figure 10-84

Acceptable - Class 1,2,3

- Blisters, scratches, voids that do not expose conductors and do not bridge adjacent conductors, conductor surfaces or create a hazardous condition which would allow loose resist particles to become enmeshed in moving parts or lodged between two electrically conductive mating surfaces.

  Note: Blisters, scratches, voids that expose circuitry are acceptable as long as they don't bridge adjacent circuitry.

- Solder flux, oil or cleaning agents are not trapped under blistered areas.

10.5.1.2 Solder Resist Coating – Voids and Blisters (cont.)

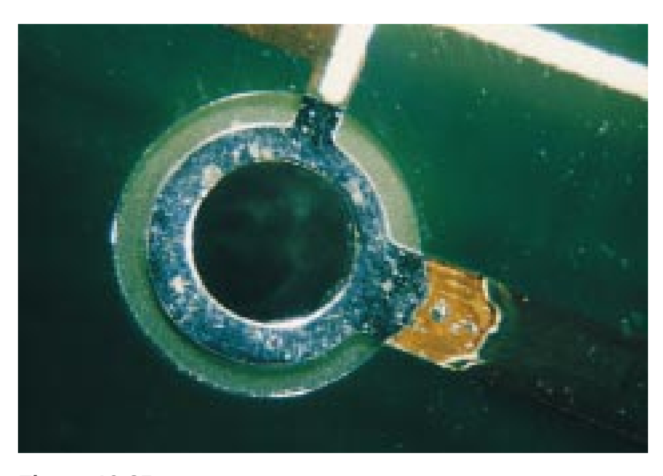


Figure 10-85

Process Indicator - Class 2,3

- Blisters/flaking expose bare copper.

Acceptable - Class 1
Defect - Class 2,3

- Coating blisters/scratches/voids allow film to flake in critical assemblies after a tape test.
- Solder fluxes, oils or cleaning agents are trapped under coating.

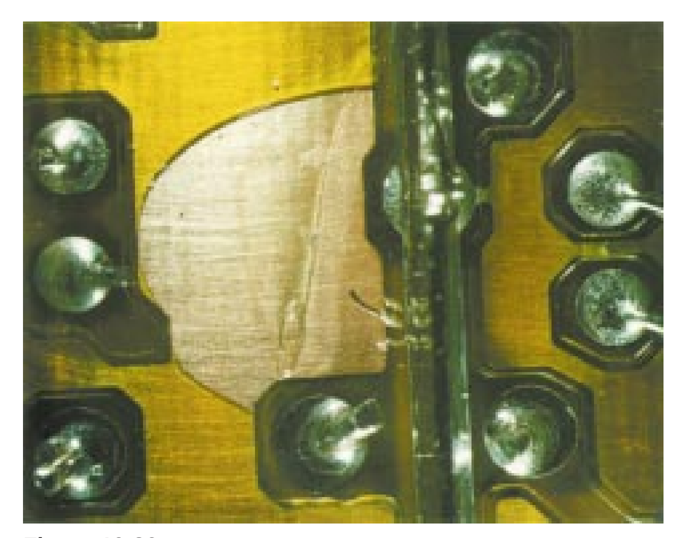


Figure 10-86

Defect - Class 1,2,3

- Coating blisters/scratches/voids bridge adjacent noncommon circuits.
- Loose particles of solder resist material that could affect form, fit or function.
- Coating blisters/scratches/voids have permitted solder bridges.

10.5.1.3 Solder Resist Coating – Breakdown

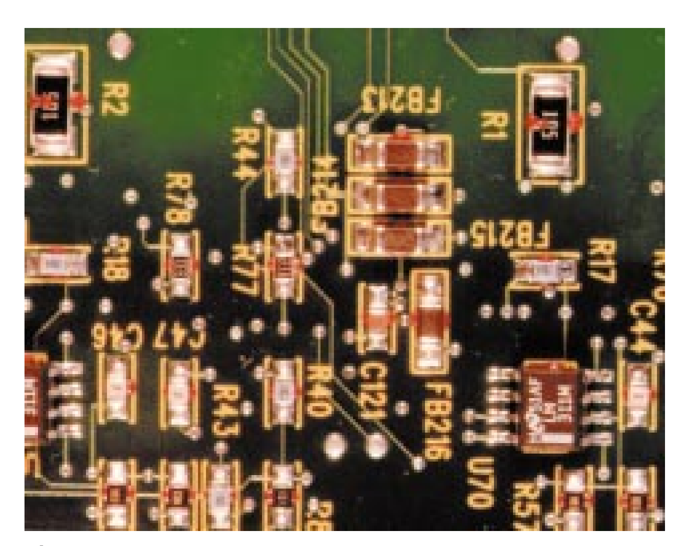


Figure 10-87

Acceptable - Class 1,2,3

- Solder resist surfaces are homogeneous with no flaking or peeling over dielectric areas.

Defect - Class 1,2,3

- Solder resist has powdery whitish appearance with possible inclusions of solder metal.

10.5.1.4 Solder Resist Coating – Discoloration

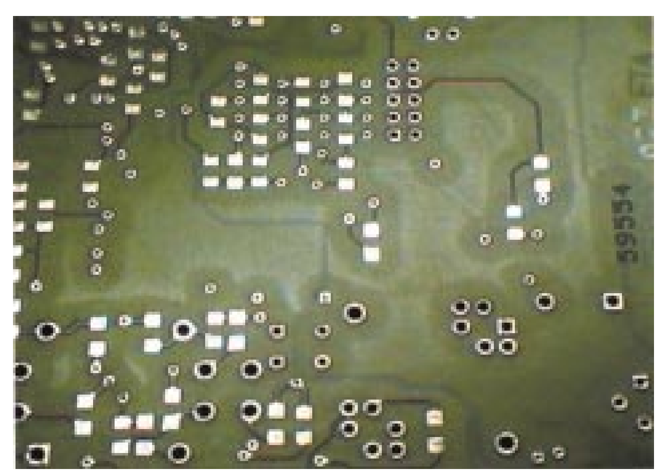


Figure 10-88

Acceptable - Class 1,2,3

- Discoloration of the solder resist material.

Defect - Class 1,2,3

- Solder resist does not comply with 10.5.1.1 through 10.5.1.3.

10.5.2 Conformal Coating

10.5.2.1 Conformal Coating – General

Conformal coatings should be transparent, uniform in color and consistency and uniformly cover the board and components. Uniform coating distribution depends partly on the method of application and may affect visual appearance and corner coverage. Assemblies coated by dipping may have a drip line or localized build-up of the edge of the board. This build-up may contain a small amount of bubbles but it will not affect the functionality or reliability of the coating.

10.5.2.2 Conformal Coating – Coverage

The assembly may be examined with the unaided eye, see 1.8. Materials that contain a fluorescent pigment may be examined with blacklight to verify coverage. White light may be used as an aid for examining coverage.

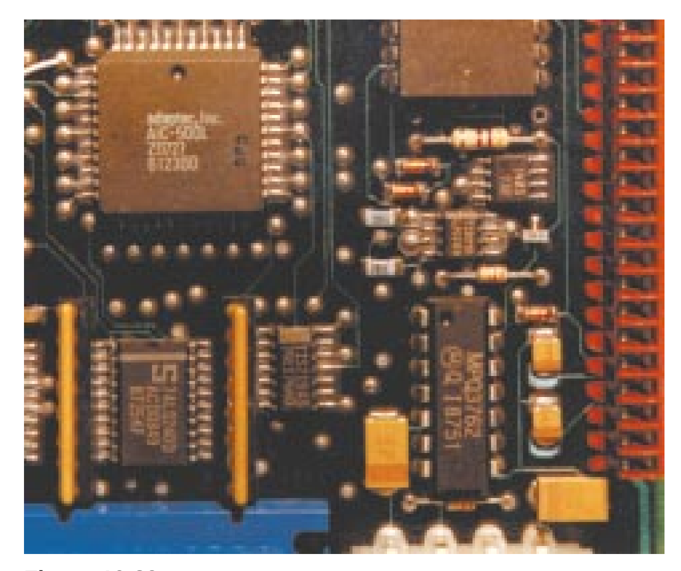
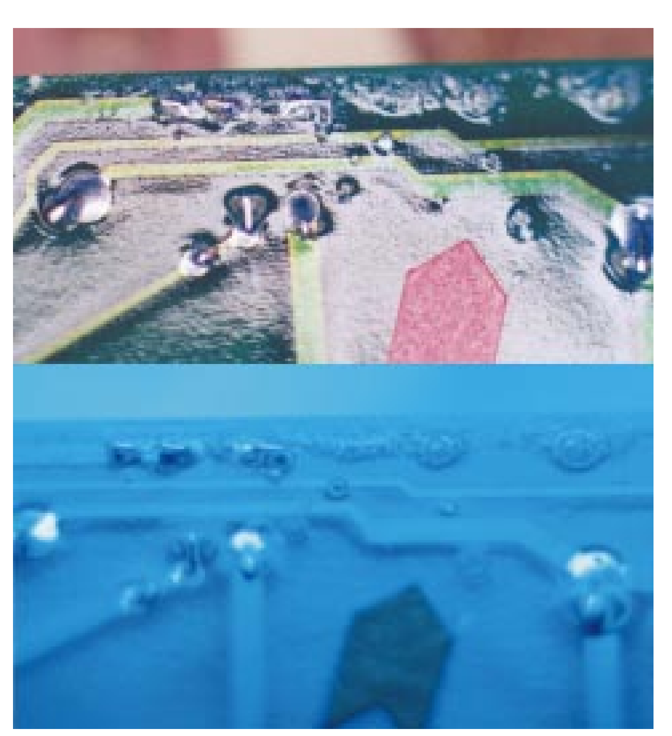


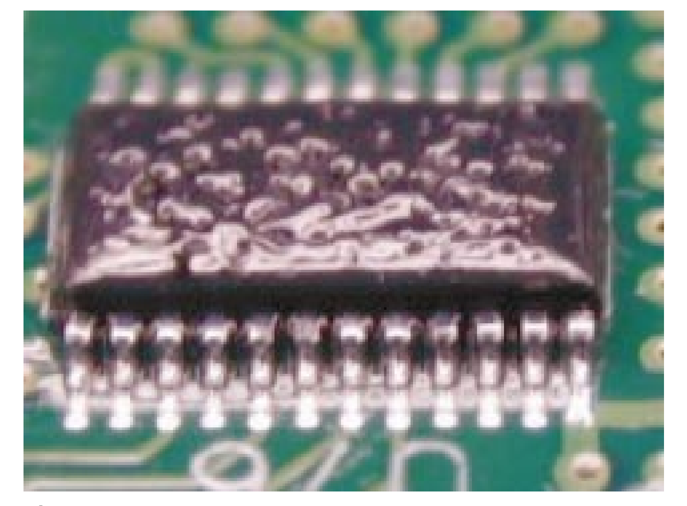
Figure 10-89

Target - Class 1,2,3

- No loss of adhesion.
- No voids or bubbles.
- No dewetting, mealing, peeling, wrinkles (nonadherent areas), cracks, ripples, fisheyes or orange peel.
- No embedded/entrapped foreign material.
- No discoloration or loss of transparency.
- Completely cured and uniform.

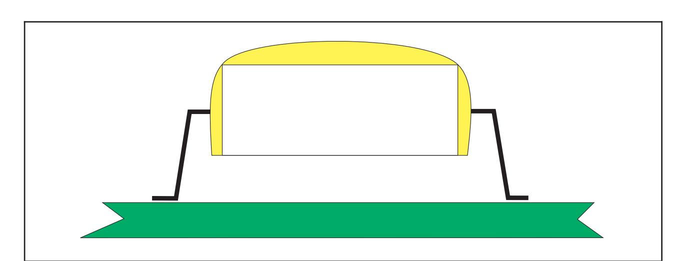
10.5.2.2 Conformal Coating – Coverage (cont.)

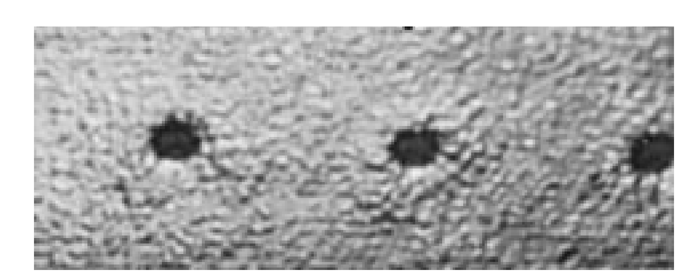

Figure 10-90


Figure 10-91

Acceptable - Class 1,2,3

- Completely cured and homogenous.
- Coating only in those areas where coating is required.
- Loss of adhesion adjacent to masking.
- No bridging of adjacent lands or conductive surfaces from:
  - loss of adhesion (mealing)
  - voids or bubbles
  - dewetting
  - cracks
  - ripples
  - fisheyes or orange peel
- Foreign material does not violate minimum electrical clearance between components, lands or conductive surfaces.
- Coating is thin but still coats component/device edges.


Figure 10-92


Figure 10-93

10.5.2.2 Conformal Coating – Coverage (cont.)

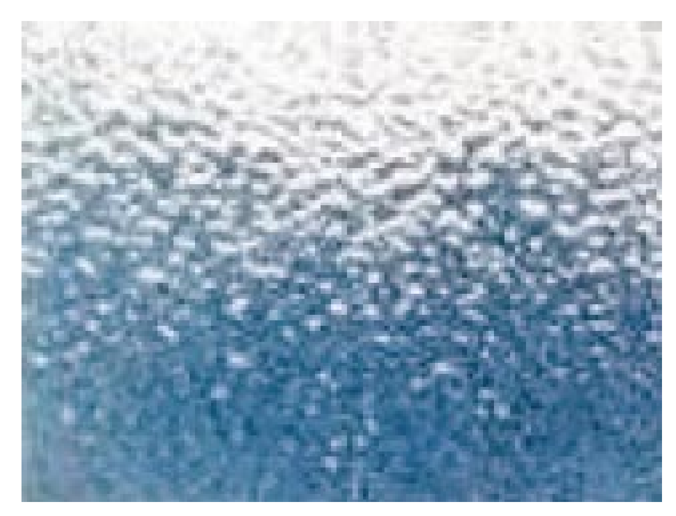


Figure 10-94

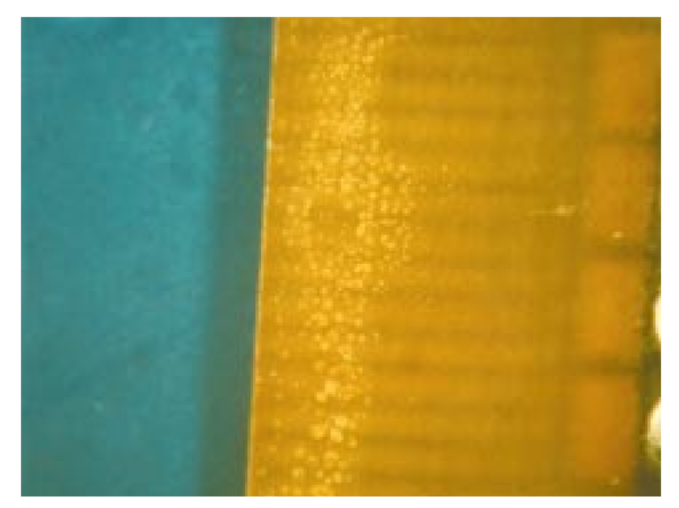


Figure 10-95



Figure 10-96

Defect - Class 1,2,3

- Coating is not cured (exhibits tackiness).
- Coating is not applied to required areas.
- Coating is on areas required to be free of coating.
- Any bridging of adjacent lands or conductive surfaces caused by:
  - loss of adhesion (mealing)
  - voids or bubbles
  - dewetting
  - cracks
  - ripples
  - fisheyes or orange peel
- Any foreign material that bridges lands or adjacent conductive surfaces, exposes circuitry or violates minimum electrical clearance between components, lands or conductive surfaces.
- Discoloration or loss of transparency.
- Coating wicking into connector housing.
- Coating wicking onto mating surfaces.

10.5.2.3 Conformal Coating – Thickness

Table 10-1 provides coating thickness requirements. The thickness is to be measured on a flat, unencumbered, cured surface of the printed circuit assembly or a coupon that has been processed with the assembly. Coupons may be of the same type of material as the printed board or may be of a non-porous material such as metal or glass. As an alternative, a wet film thickness measurement may be used to establish the coating thickness provided there is documentation that correlates the wet and dry film thickness.

Note: Table 10-1 of this standard is to be used for printed circuit assemblies. The coating thickness requirements in IPC-CC-830 are to be used only for test vehicles associated with coating material testing and qualification.

Table 10-1 Coating Thickness

Type AR	Acrylic Resin	0.03-0.13 mm [0.00118-0.00512 in]
Type ER	Epoxy Resin	0.03-0.13 mm [0.00118-0.00512 in]
Type UR	Urethane Resin	0.03-0.13 mm [0.00118-0.00512 in]
Type SR	Silicone Resin	0.05-0.21 mm [0.00197-0.00827 in]
Type XY	Paraxylene Resin	0.01-0.05 mm [0.00039-0.00197 in]

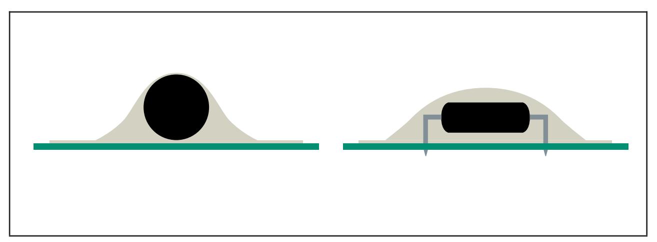


Figure 10-97

Acceptable - Class 1,2,3

- Coating meets the thickness requirements of Table 10-1.

Defect - Class 1,2,3

- Coating does not meet thickness requirements of Table 10-1.



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11 Discrete Wiring

Discrete wiring refers to a substrate or base upon which discrete wiring techniques are used to obtain electronic interconnections. Separate visual criteria for each type are depicted in this section.

Discrete Wiring Acceptability Guidelines

The routing and terminating of discrete wires to form point-to-point electrical connections by use of special machines or tools may be employed to replace or supplement printed conductors on board assemblies. Application may be in planar, two-dimensional or three-dimensional configurations.

This section defines the criteria for acceptability of interconnections produced by some of the important discrete wiring processes in electronic assemblies. The illustrations are presented to depict particular characteristics of the techniques. They are classified in the following categories:

1. Semi-Permanent Connections
2. Permanent Connections

In addition to the criteria in this section, solder connections must meet the criteria of Section 5.

The following topics are addressed in this section:

11.1 Solderless Wrap

This section establishes visual acceptability criteria for connections made by the solderless wrap method. It is assumed that the terminal/wire combination has been designed for this type of connection.

The tightness of the wire wrap should be validated by the tool verification process.

It is also assumed that a monitoring system exists that uses test connections to verify that the operator/tooling combination is capable of producing wraps that meet strip force requirements.

Depending on the service environment, the connecting instructions will specify whether the connection will be conventional or modified.

Once applied to the terminal, an acceptable solderless wrap connection must not be subjected to excessive heat nor have any mechanical operations performed on it.

It is not acceptable to attempt to correct a defective connection by reapplying the wrapping tool or by applying other tools.

The reliability and maintainability advantages of the solderless wrap connection method are such that no repair of a defective wrap by soldering is to be made. The defective connections must be unwrapped using a special tool (not stripped off the terminal) and then a new wire wrapped to the terminal. New wire must be used for each wrap/rewrap, but the terminal may be rewrapped many times.

11.1.1 Solderless Wrap – Number of Turns

For this requirement, countable turns are those turns of bare wire in intimate contact with the corners of the terminal starting at the first contact of bare wire with a terminal corner and ending at the last contact of bare wire with a terminal corner; see Table 11-1.

A modified wrap is required for Class 3. It has an additional amount of insulated wire wrapped to contact at least three corners of the terminal.

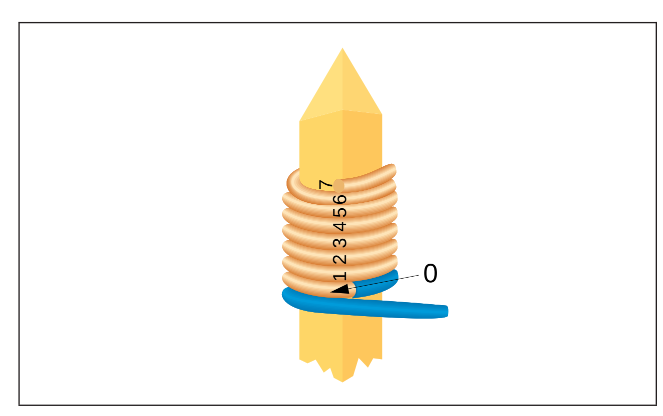


Figure 11-1

Target - Class 1,2,3

- One half (50%) more turn than the minimum shown in Table 11-1.

Acceptable - Class 1,2

- Countable turns meet the requirements of Table 11-1.

Acceptable - Class 3

- Countable turns meet the requirements of Table 11-1.
- Meets requirements of modified wrap.

Table 11-1 Minimum Turns of Bare Wire

Wire Gauge	Turns
30	7
28	7
26	6
24	5
22	5
20	4
18	4

Note: Maximum turns of bare and insulated wire is governed only by tooling configuration and space available on the terminal.

Defect - Class 1,2,3

- Number of countable turns does not comply with Table 11-1.

Defect - Class 3

- Does not meet requirements of modified wrap.

11.1.2 Solderless Wrap – Turn Spacing

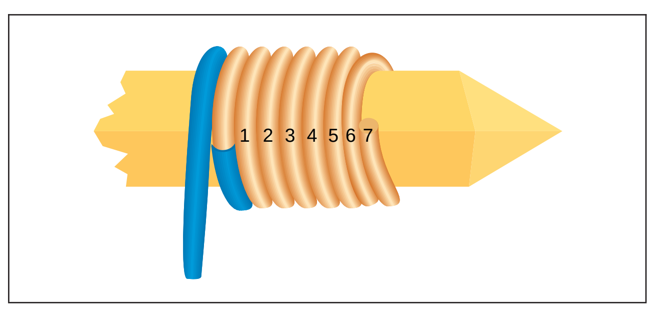


Figure 11-2

Target - Class 1,2,3

- No space between any turns.

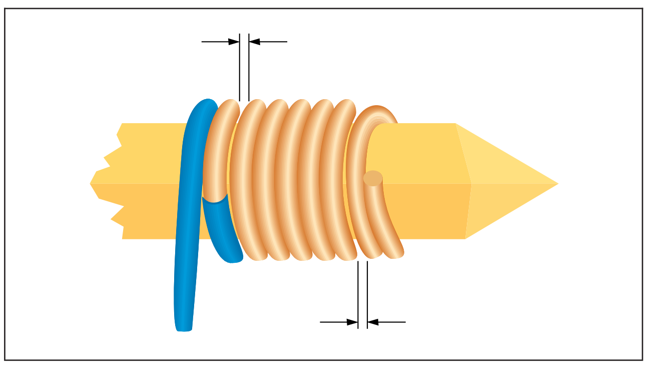


Figure 11-3

Acceptable - Class 1

- No space over one wire diameter.

Acceptable - Class 2

- No space over 50% diameter of wire within countable turns.
- No space over one wire diameter elsewhere.

Acceptable - Class 3

- No more than three turns spaced apart.
- No space over 50% diameter of wire within the wrap.

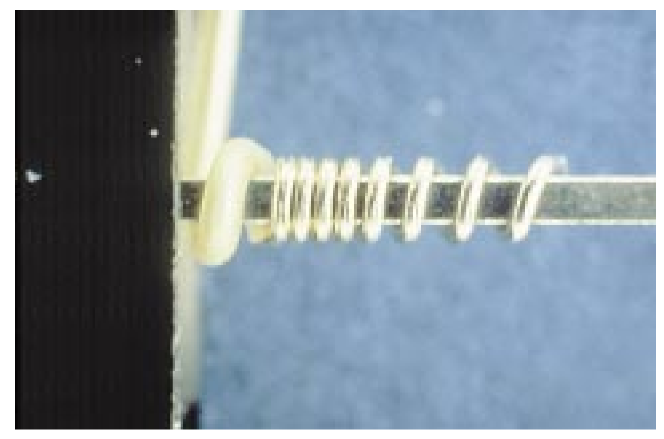


Figure 11-4

Defect - Class 1

- Any space over one wire diameter.

Defect - Class 2

- Any space over half wire diameter within countable turns.

Defect - Class 3

- Any space more than half wire diameter.
- More than three spaces any size.

11.1.3 Solderless Wrap – End Tails, Insulation Wrap

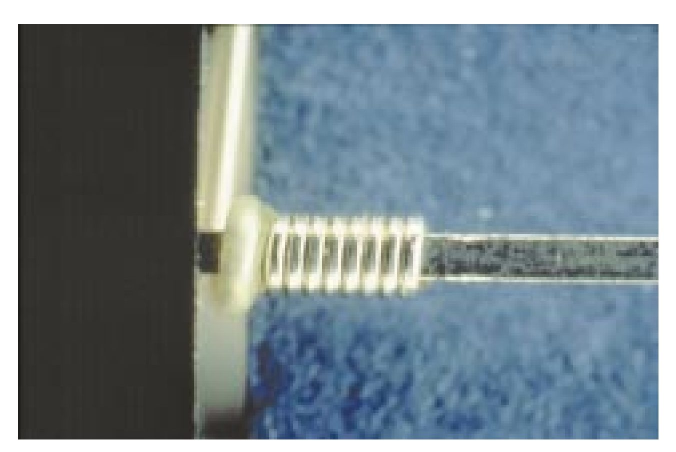


Figure 11-5

Target - Class 1,2

- End tail does not extend beyond outer surface of wrap.
- Insulation reaches terminal.

Target - Class 3

- End tail does not extend beyond outer surface of wrap with insulation modified wrap (see 11.1.1).

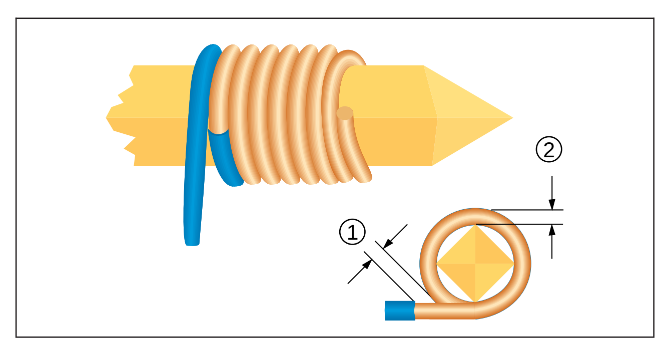


Figure 11-6
1. Insulation clearance
2. Wire diameter (viewed from bottom)

Acceptable - Class 1

- Does not violate minimum electrical clearance.
- Exposed conductor in the insulation.

Acceptable - Class 2

- Insulation end meets clearance requirements to other circuitry.
- End tail does not extend more than 3 mm [0.12 in] from outer surface of wrap.

Acceptable - Class 3

- End tail projects no more than one wire diameter from outer surface of wrap.
- Insulation must contact minimum of three corners of post.

11.1.3 Solderless Wrap – End Tails, Insulation Wrap (cont.)

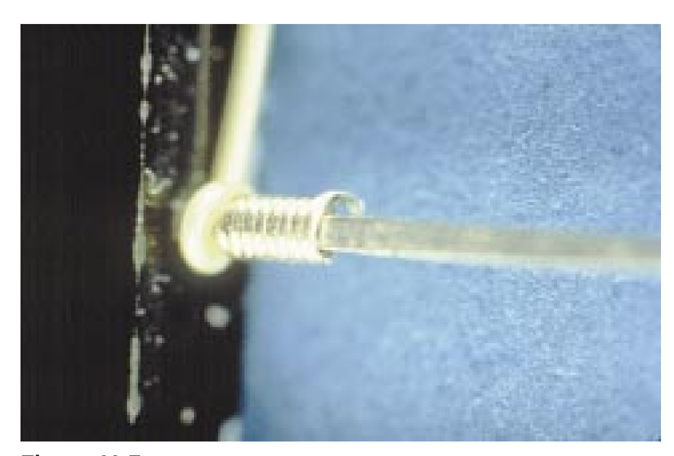


Figure 11-7

Acceptable - Class 1
Defect - Class 2,3

- End tail is greater than 3 mm [0.12 in].

Defect - Class 3

- End tail is greater than one wire diameter.



Figure 11-8

Defect - Class 1,2,3

- End tail violates minimum electrical clearance.

11.1.4 Solderless Wrap – Raised Turns Overlap

Raised turns are squeezed out of the helix, therefore no longer have intimate contact with the terminal corners. Raised turns may overlap or override other turns.

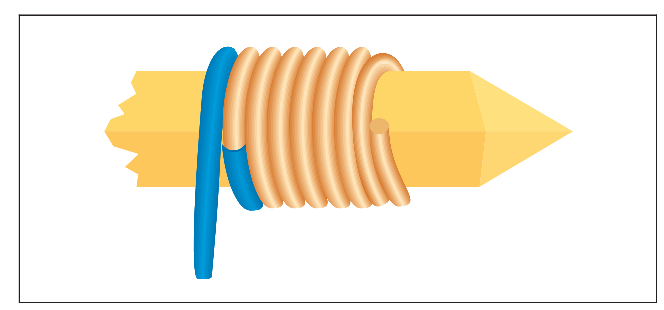


Figure 11-9

Target - Class 1,2,3

- No raised turns.

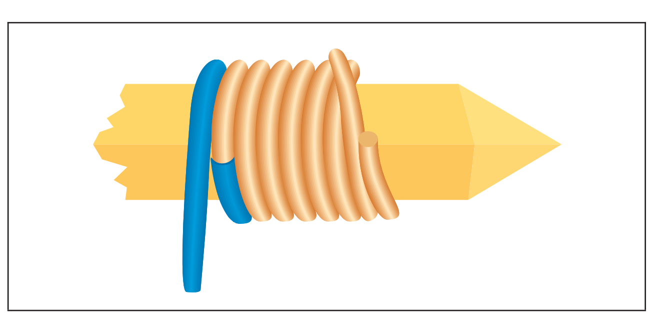


Figure 11-10

Acceptable - Class 1

- Raised turns anywhere provided remaining total turns still have contact and meet minimum turns requirement.

Acceptable - Class 2

- No more than half turn raised within countable turns, any amount elsewhere.

Acceptable - Class 3

- No raised turns within countable turns, any amount elsewhere.

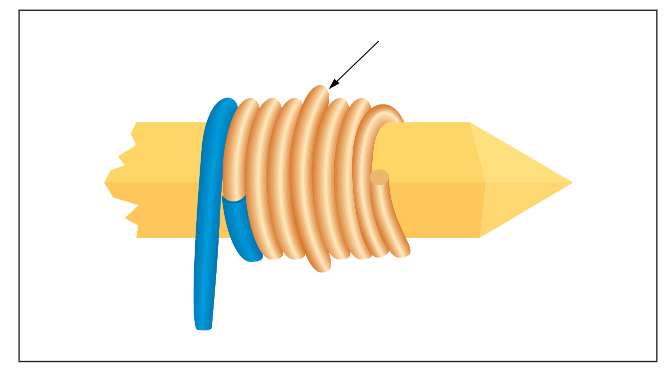


Figure 11-11

Defect - Class 1

- Remaining total turns that still have contact do not meet minimum turn requirements.

Defect - Class 2

- More than half raised turn within countable turns.

Defect - Class 3

- Any raised turns within countable turns.

11.1.5 Solderless Wrap – Connection Position

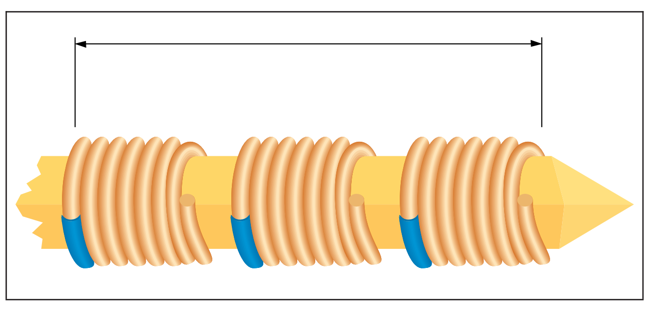


Figure 11-12

Target - Class 1,2,3

- All turns of each connection on working length of terminal.
- Visible separation between each connection.

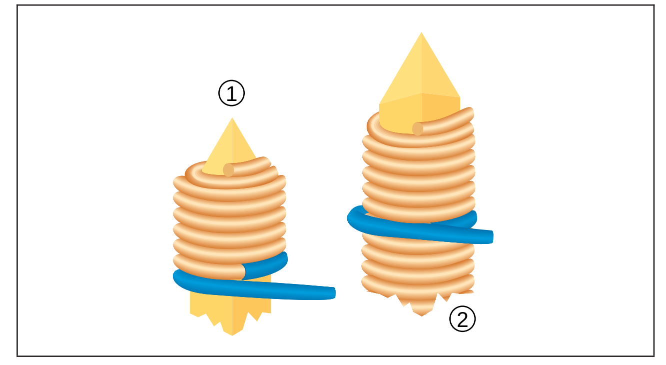


Figure 11-13
1. Wrap extends above working length
2. Insulation turn overlaps previous wrap

Acceptable - Class 1,2

- Extra turns of bare wire or any turns of insulated wire (whether or not for modified wrap) beyond end of working length of terminal.

Acceptable - Class 1

- Extra turns of bare wire or any turns of insulated wire overlap a preceding wrap.

Acceptable - Class 2

- Turns of insulated wire only overlap a preceding wrap.

Acceptable - Class 3

- Wraps may have an insulated wire overlap the last turn of uninsulated wire.
- No turns of bare or insulated wire beyond either end of working length.

11.1.5 Solderless Wrap – Connection Position (cont.)

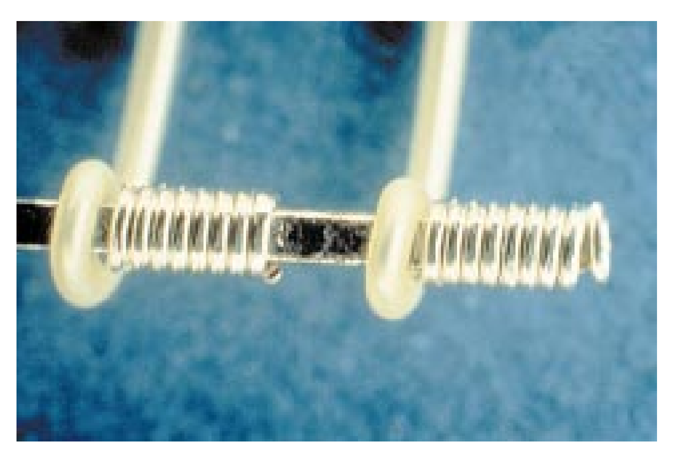


Figure 11-14

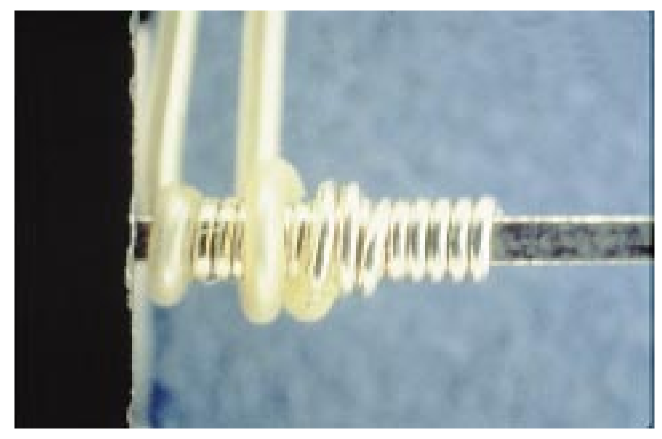


Figure 11-15

Defect - Class 1,2,3

- Insufficient number of countable turns in contact with the terminal.
- Wire overlaps the wire turns of a preceding connection.

11.1.6 Solderless Wrap – Wire Dress

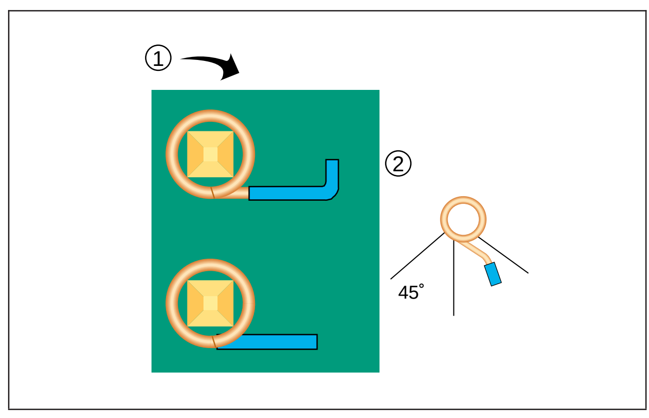


Figure 11-16
1. Direction of turns
2. Proper radius

Acceptable - Class 1,2,3

- The dress of wire needs to be oriented so that force exerted axially on the wire will not tend to unwrap the connection, or to relieve the bite of wire on the corners of the terminal post. This requirement is satisfied when the wire is routed so as to cross the 45° line as shown.

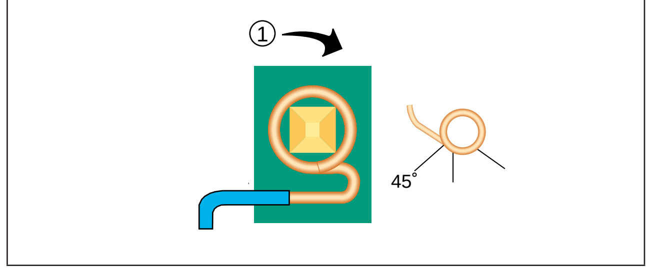


Figure 11-17
1. Direction of turns

Defect - Class 1,2,3

- Axially exerted external forces on the wrap will cause the wrap to unwind or loosen the wire bite at the post corners.

11.1.7 Solderless Wrap – Wire Slack

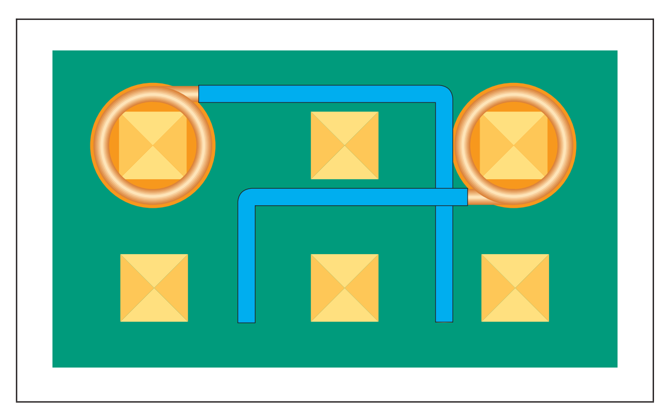


Figure 11-18

Acceptable - Class 1,2,3

- Wiring needs to have sufficient slack so that it will not pull around corners of the other terminal posts or bridge and load other wires.

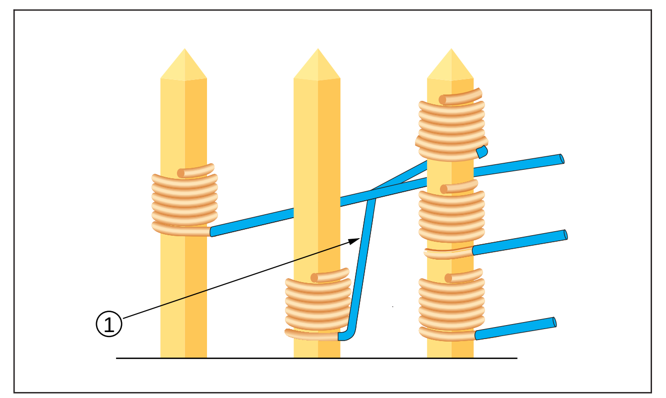


Figure 11-19
1 Wire crossing

Defect - Class 1,2,3

- Insufficient wire slack causing:
  - Abrasion between wire insulation and wrap post.
  - Tension on wires between wrap post causing distortion of posts.
  - Pressure on wires that are crossed by a taut wire.

11.1.8 Solderless Wrap – Wire Plating

Plating

Wire used for solderless wrap is normally plated to improve connection reliability and minimize subsequent corrosion.

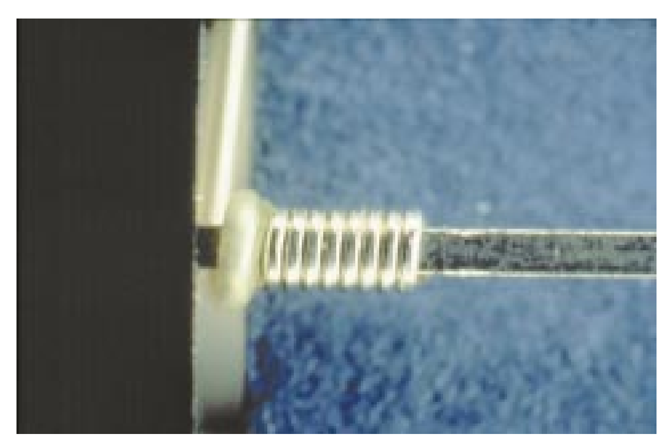


Figure 11-20

Target - Class 1,2,3

- After wrapping, uninsulated wire has no exposed copper.

Acceptable - Class 1

- Exposed copper.

Acceptable - Class 1,2

- Up to 50% of countable turns show exposed copper.

Defect - Class 2

- More than 50% of countable turns show exposed copper.

Defect - Class 3

- Any exposed copper (last half turn and wire end excluded).

11.1.9 Solderless Wrap – Damaged Insulation

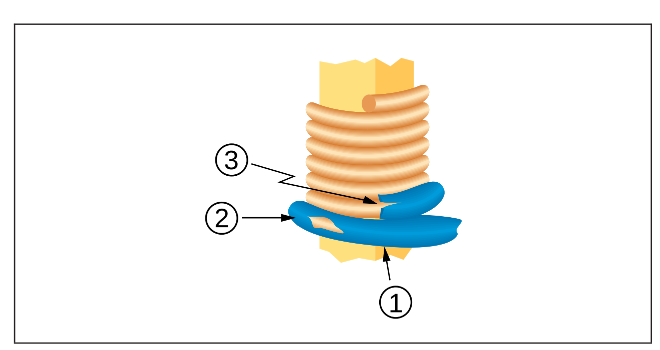


Figure 11-21
1. Initial corner
2. Insulation split
3. Insulation cut or frayed

Acceptable - Class 1,2,3

- After initial contact with post:
  - Insulation damage.
  - Splits.
  - Cut or fraying on the wrap.

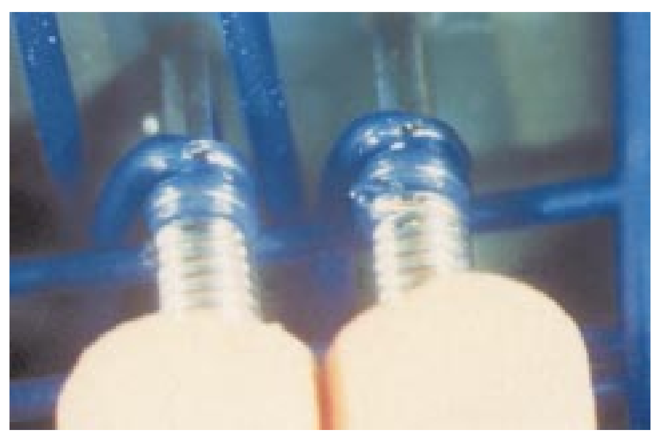


Figure 11-22

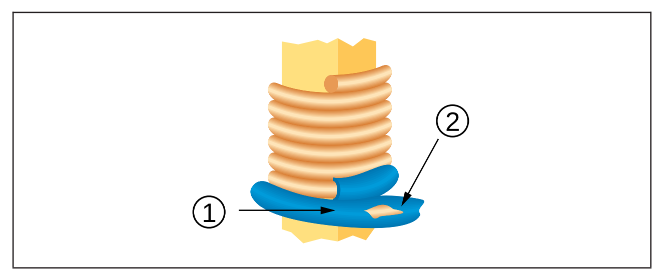


Figure 11-23
1. Initial contact corner
2. Split insulation, etc., between wrap terminal. Conductor is exposed.

Defect - Class 1,2,3

- Minimum electrical clearance violated.

Defect - Class 2,3

- Splits, cuts or fraying of insulation between wrap terminals prior to initial contact corner of post.
- Spacing requirements are violated.

11.1.10 Solderless Wrap – Damaged Conductors & Terminals

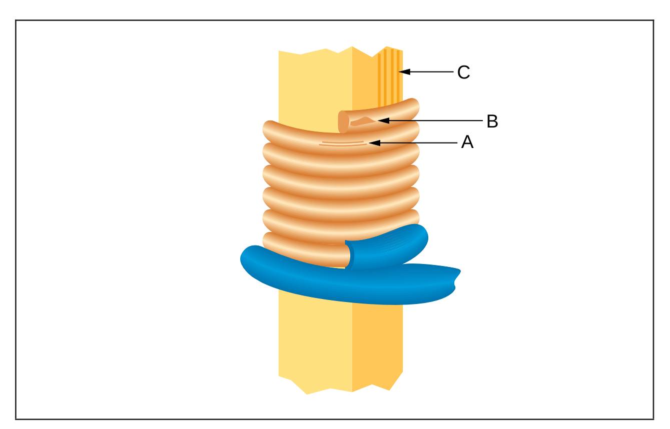


Figure 11-24

Target - Class 1,2,3

- Wire finish is not burnished or polished, nicked, scraped, gouged or otherwise damaged.
- Wire wrap terminals are not burnished, scraped or otherwise damaged.

Acceptable - Class 1,2,3

- Finish on the wire is burnished or polished (slight tool marks) (A).
- The top or last turn damaged from the wrap tool such as nicks, scrapes, gouges, etc., not exceeding 25% of wire diameter (B).
- Damage to terminal caused by tool such as burnishing, scraping, etc. (C)

Acceptable - Class 1,2
Defect - Class 3

- Base metal is exposed on terminal.

11.2 Jumper Wires

These criteria do not constitute authority for repair to assemblies without prior customer consent; see 1.1. This section establishes visual acceptability criteria for the installation of discrete wires (jumper wires, haywires, etc.) used to interconnect components where there is no continuous printed circuit.

The requirements relative to wire type, wire routing, staking and soldering requirements are the same for both haywires and jumper wires. For the sake of simplicity only the more common term, jumper wires, is used in this section, however these requirements would apply to both haywires and jumper wires.

Information concerning rework and repair can be found in IPC-7711A/7721A.

The following items are addressed:

- Wire type
- Wire routing
- Adhesive staking of wire
- Solder termination

They may be terminated in plated holes, and/or to terminal standoffs, conductor lands, and component leads.

Jumper wires are considered as components and are covered by an engineering instruction document for routing, termination, staking and wire type.

Keep jumper wires as short as practical and unless otherwise documented do not route over or under other replaceable components. Design constraints such as real estate availability and minimum electrical clearance need to be taken into consideration when routing or staking wires. A jumper wire 25 mm [0.984 in] maximum in length whose path does not pass over conductive areas and do not violate the designed spacing requirements may be uninsulated. Insulation, when required on the jumper wires, needs to be compatible with conformal coating.

11.2.1 Jumper Wires – Wire Selection

The following considerations are to be made when selecting wires for jumpers:

1. Wire is insulated if greater than 25 mm [0.984 in] in length or is liable to short between lands or component leads.
2. Silver plated stranded wire should not be used. Under some conditions corrosion of the wire can occur.
3. Select the smallest diameter wire that will carry the required current needs.
4. The insulation of the wire should withstand soldering temperatures, have resistance to abrasion, and have a dielectric resistance equal to or better than the board insulation material.
5. Recommended wire is solid, insulated, plated copper wire.
6. Chemical solutions, pastes, and creams used to strip solid wires do not cause degradation to the wire.

11.2.2 Jumper Wires – Wire Routing

Unless otherwise specified by high speed/high frequency requirements, route jumper wires the shortest route in straight legs as possible, avoiding test points, to points of termination. Allow enough length for routing, stripping and attachment.

Jumper wire routing on assemblies having the same part number should be the same pattern.

Routing needs to be documented for each part number and followed without deviation.

On the primary side, do not allow jumper wires to pass over or under any component, however, they may pass over parts such as thermal mounting plates, brackets and components that are bonded to the PWB.

On the primary side jumpers may pass over solder lands if sufficient slack is provided so they can be moved away from the solder land for component replacement.

Contact with heat sinks specific to high temperature generating components must be avoided.

On secondary side, except for connectors at the edge of the board, do not pass jumpers through component foot prints unless the layout of the assembly prohibits the routing in other areas.

On the secondary side, do not pass jumpers over patterns or vias used as a test point.

11.2.2 Jumper Wires – Wire Routing (cont.)

Target - Class 1,2,3

- Wire routed shortest route.
- Wire does not pass over or under component.
- Wire does not pass over land patterns or vias used as test points.
- Wire does not cross component footprint or lands.

Acceptable - Class 1,2,3

- Lands not covered by wire.
- Sufficient slack in wire to allow relocation from unavoidable lands during component replacement or test.

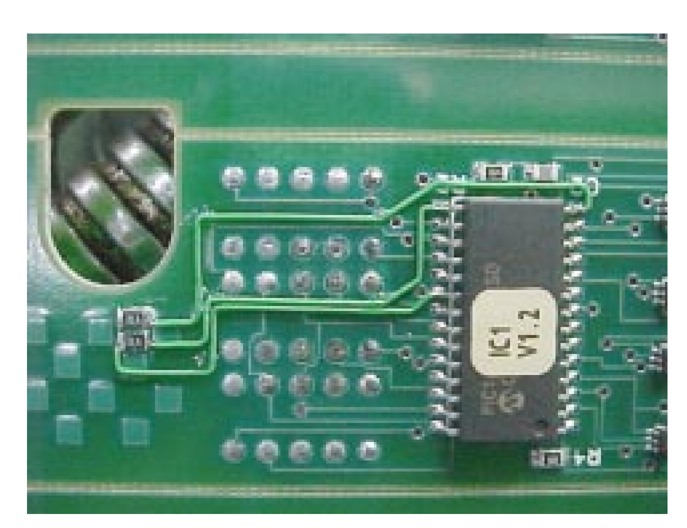


Figure 11-25

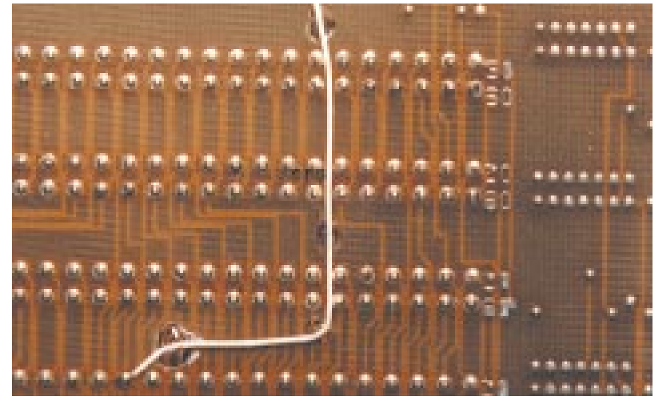


Figure 11-26

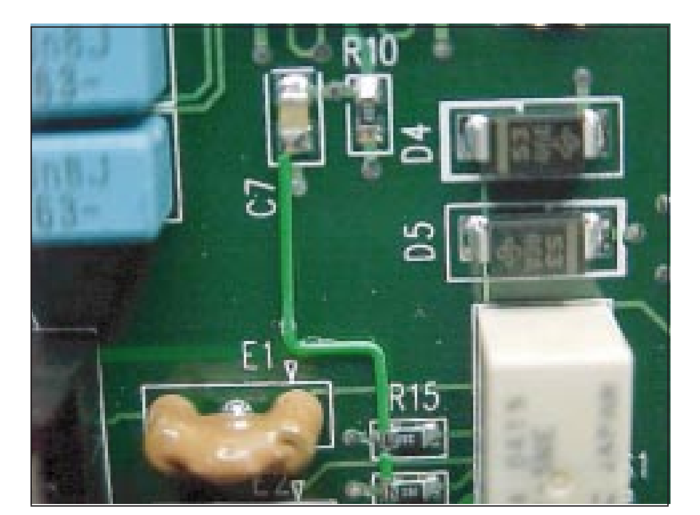


Figure 11-27

11.2.2 Jumper Wires – Wire Routing (cont.)

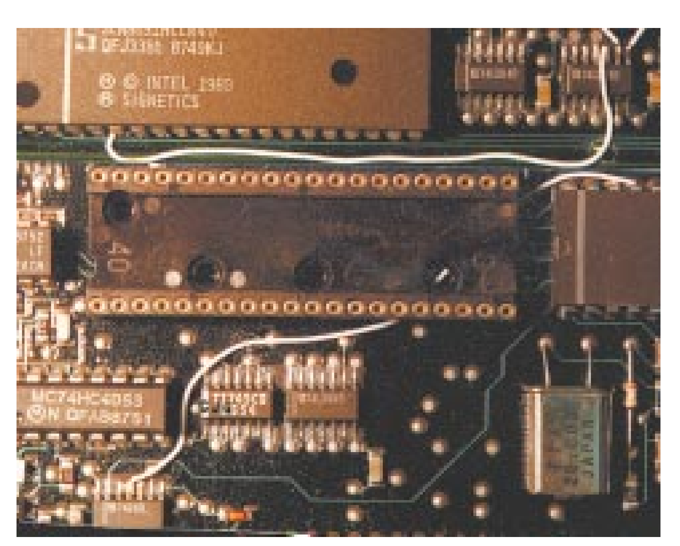


Figure 11-28

Acceptable - Class 1
Process Indicator - Class 2,3

- Insufficient slack in wire to allow relocation from unavoidable lands during component replacement.
- Unavoidable crossing of component footprint or land area.

Acceptable - Class 1
Defect - Class 2,3

- Wire routed under or over components.

Note: Take in consideration the trapping of contaminants when wires are routed under components. When routed over components consider the implications of wires coming in contact with heat sinks or hot components and electrical interference in RF applications.

11.2.3 Jumper Wires – Wire Staking

Jumper wires may be staked to the base material (or integral thermal mounting plate or hardware) by adhesive or tape (dots or strips). When adhesive is used, it is to be mixed and cured in accordance with the manufacturer's instructions. All adhesive must be fully cured before acceptance. Consider the end-use product environment as well as subsequent process compatibility when selecting the appropriate staking method.

Spot bond so that the stake fillet is sufficient to secure the wire with no excessive spillover onto adjacent lands or components.

Staking is not to be on a removable or socketed component. Where design constraints are an obstacle, staking is to be discussed with the customer.

Jumper wires are not to be staked to, or allowed to touch, any moving parts. Wires are staked within the radius of each bend for each change of direction.

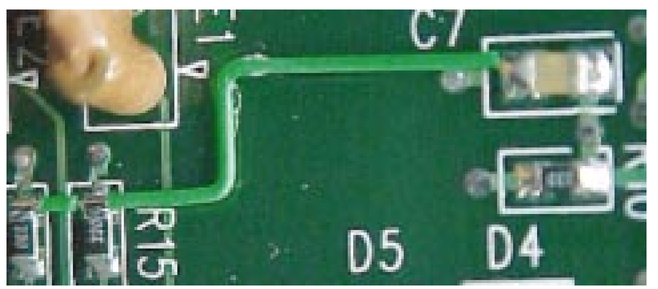


Figure 11-29

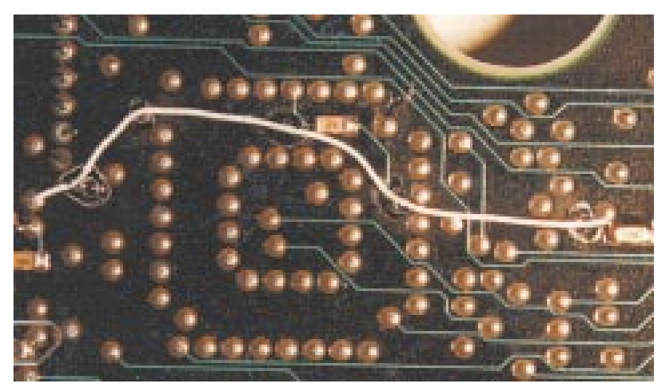


Figure 11-30

Acceptable - Class 1,2,3

- Jumper wires are staked at intervals as specified by engineering documentation or:
  - At all changes of direction to restrict movement of wire.
  - As close to the solder connection as possible.
- The wire is not so loose that it can extend above the height of adjacent components when pulled taut.
- Staking tape/adhesive do not overhang the board edge(s) or violate edge spacing requirements.

11.2.3 Jumper Wires – Wire Staking (cont.)

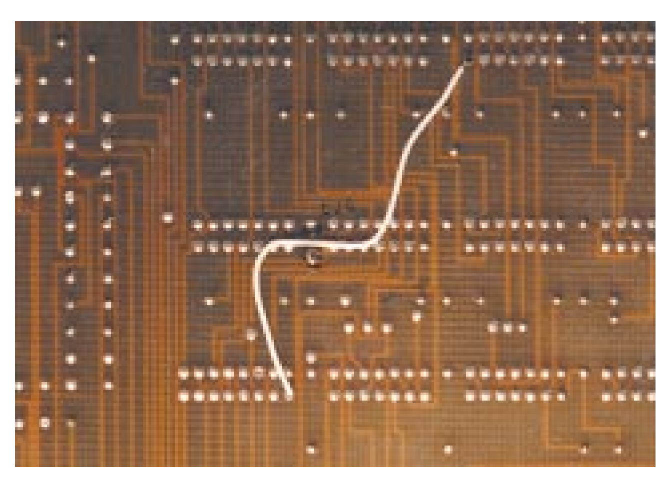


Figure 11-31

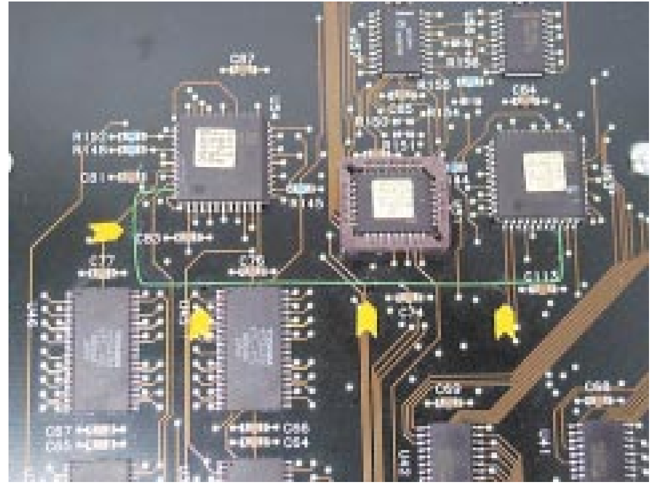


Figure 11-32

Acceptable - Class 1
Defect - Class 2,3

- The wire is loose and can extend above the height of adjacent components when pulled taut.
- Jumper wires are not staked.
- Staking tape/adhesive overhang the board edge(s) or violate edge spacing requirements.

11.2.4 Jumper Wires – Plated-Through Holes

Jumper wires may be attached by any of the following methods. However, the method used for a particular assembly type needs to be defined.

This section is intended to show jumper wire practices that are used in original manufacturing. See IPC-7711A/7721A for additional jumper wire information when affecting repairs and modifications.

For jumper wires attached to components other than axial leaded, lap solder the wire to the component lead. Assure the solder connection length and insulation clearance meet the minimum/maximum acceptability requirements.

11.2.4.1 Jumper Wires – PTH/Via – Lead in Hole

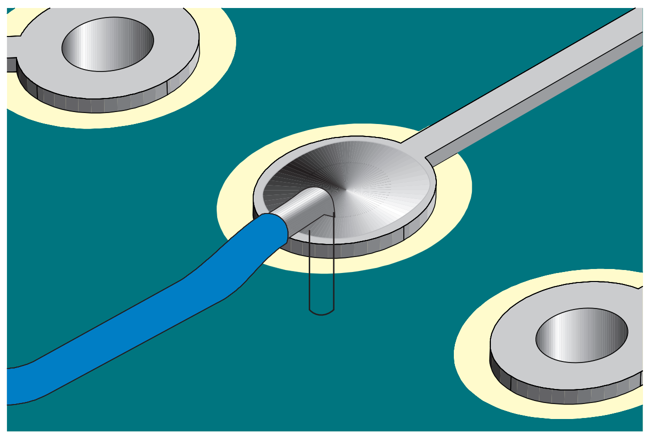
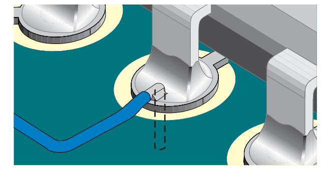


Figure 11-33

Acceptable - Class 1,2,3

- Wires soldered into a PTH/Via hole.



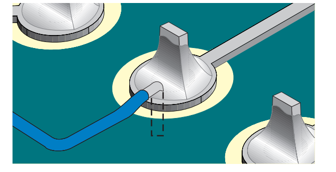


Figure 11-34

Acceptable - Class 1,2
Defect - Class 3

- Wire soldered into PTH with component lead.

11.2.4.2 Jumper Wires – PTH – Wrapped Attachment

The jumper wire ends are attached to component lead projections by wrapping the wire.

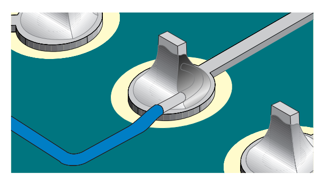
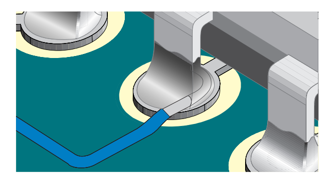



Figure 11-35

Target - Class 1,2,3

- Wire is wrapped 180° to 270° and soldered to a component lead.

Acceptable - Class 1,2,3

- Wire is wrapped a minimum of 90° on a flat lead or 180° on a round lead.
- Acceptable solder connection at wire/lead interface.
- Wire contour or end is discernible in the solder connection.
- No insulation in solder.
- Wire overhang of component termination does not violate minimum electrical clearance.



Figure 11-36

Defect - Class 1,2,3

- Wire is wrapped less than 90° on flat or less than 180° on round leads.
- Insulation is in the solder connection.
- Wire overhang violates minimum electrical clearance.

11.2.4.3 Jumper Wires – PTH – Lap Soldered

For jumper wires attached to components other than axial leaded, lap solder the wire to the component lead.

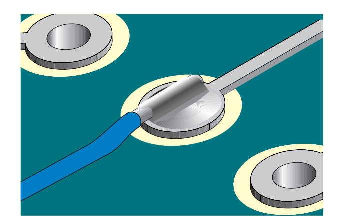
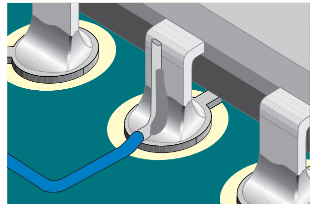



Figure 11-37

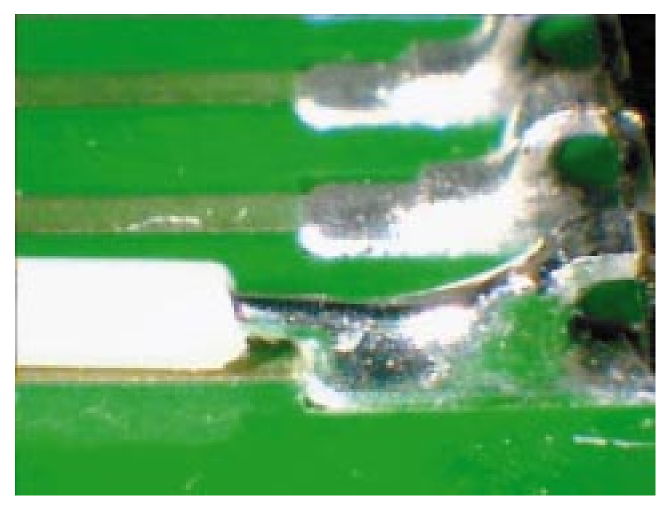


Figure 11-38

Acceptable - Class 1,2,3

- Wire is lap soldered to a component lead a minimum of 75% of (L) (from edge of land to knee of lead).
- Wire is lap soldered to a PTH/via surface.
- Acceptable solder connection at wire/lead interface.
- Wire discernible in the solder.
- The insulation is in contact with the solder but does not interfere with formation of an acceptable connection.
- Wire overhanging or extending beyond land or knee of component lead does not violate minimum electrical clearance.

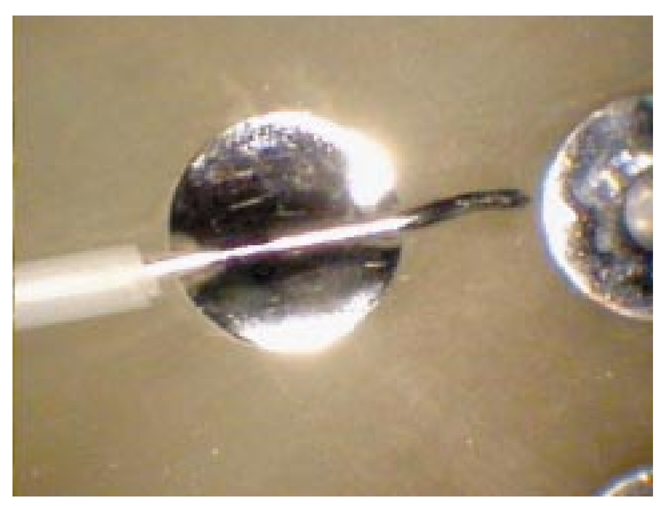


Figure 11-39

Defect - Class 1,2,3

- Wire that is lap soldered is less than 75% (L) (from edge of land to knee of lead). Insulation interferes with formation of the solder connection.
- Wire overhang violates minimum electrical clearance.

11.2.4.3 Jumper Wires – PTH – Lap Soldered (cont.)

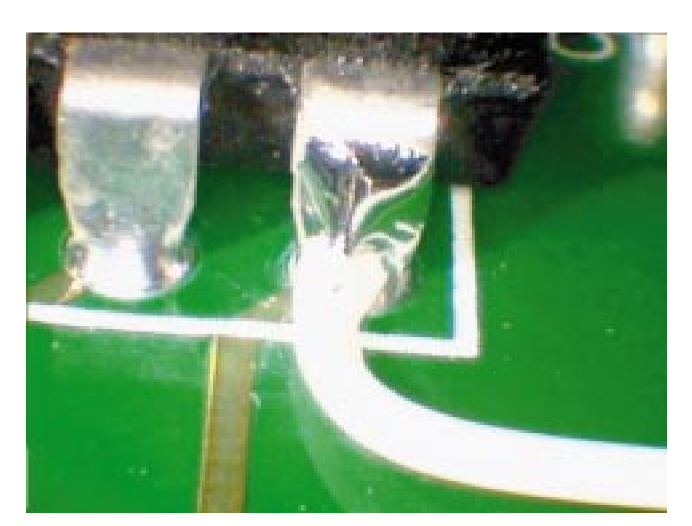


Figure 11-40

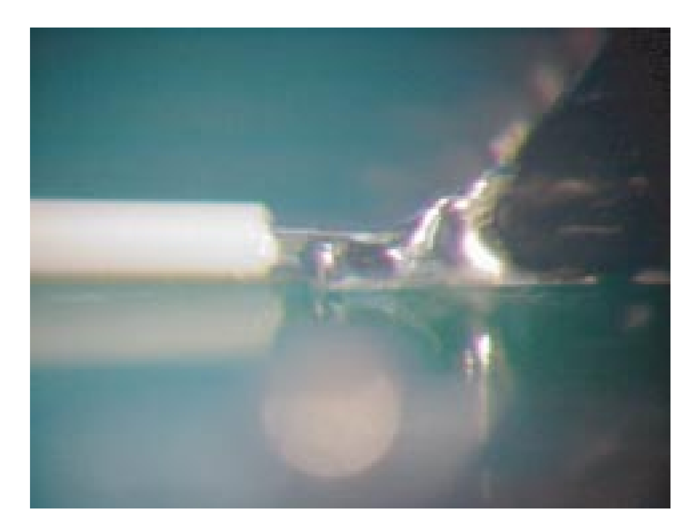


Figure 11-41

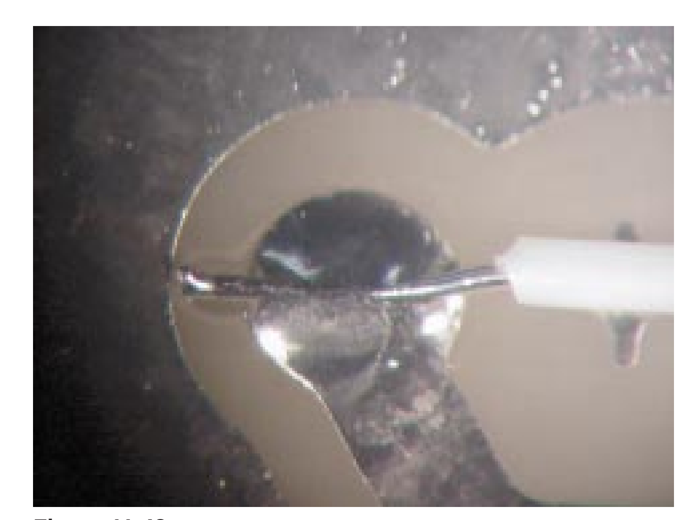


Figure 11-42

11.2.5 Jumper Wires – SMT

There is no adhesive on component bodies, leads or lands. Adhesive deposits do not obscure or interfere with solder connections.

For all lap solder connections described in this section the following conditions are acceptable:

- Insulation clearance does not permit shorting to noncommon conductors or violate minimum electrical clearance.
- Insulation in contact with the solder connection does not interfere with formation of the fillet.
- Evidence of wetting of jumper wire and lead/land.
- Wire contour or end is discernible in the solder connection.
- No fractures in solder connection.
- Wire overhang does not violate minimum electrical clearance.

Note: For applications of high frequency, i.e., RF, leads extending above the knee of the component could present problems.

11.2.5.1 Jumper Wires – SMT – Chip and Cylindrical End Cap Components

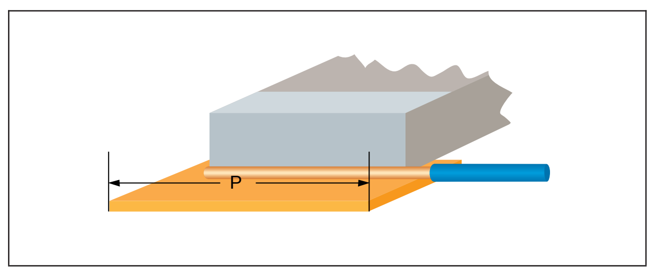


Figure 11-43

Target - Class 1,2,3

- Lead is positioned parallel to longest dimension of the land.
- Solder fillet equal to land width (P).

Acceptable - Class 1,2,3

- Wire to component termination-land solder connection is 50% of land width (P) or greater.

Defect - Class 1,2,3

- Wire to component termination-land solder connection length is less than 50% of land width (P).
- Wire soldered on top of chip component termination.

11.2.5.2 Jumper Wires – SMT – Gull Wing

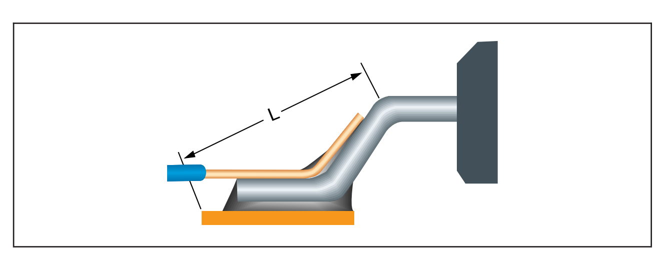


Figure 11-44

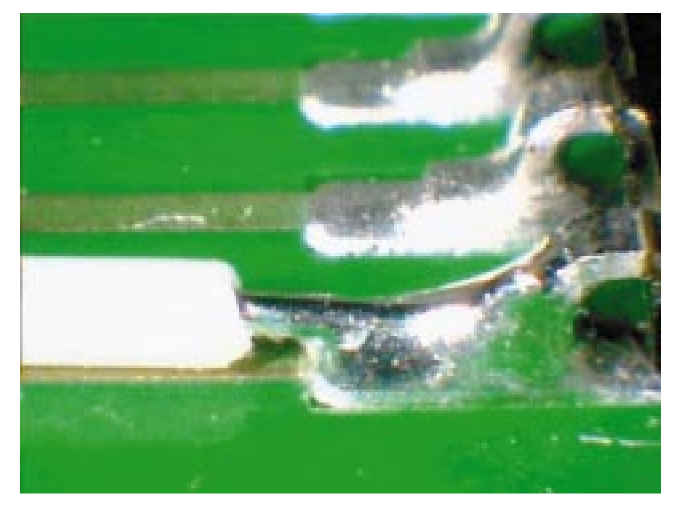


Figure 11-45

Acceptable - Class 1,2,3

- Minimum length of the wire to lead-land interface solder connection is 75% of the length (L) (from edge of land to knee of lead).
- The wire end does not extend past the lead knee bend.



Figure 11-46

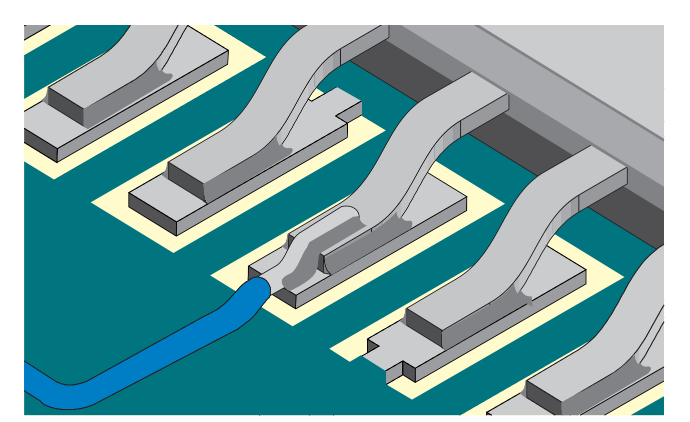


Figure 11-47

Defect - Class 1,2,3

- Fractured solder connection.
- Wire to lead-land interface solder connection less than 75% of (L).
- Wire end extends past knee of bend.
- Wire violates minimum electrical clearance.

11.2.5.3 Jumper Wires – SMT – J Lead

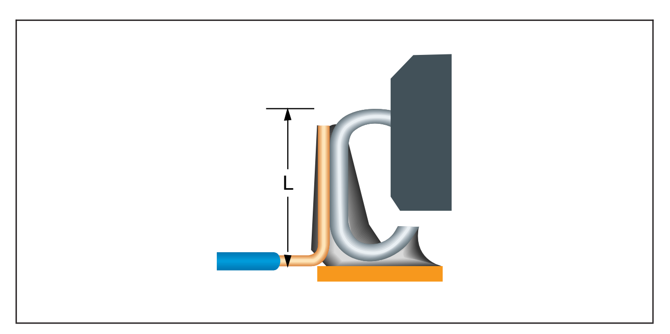


Figure 11-48

Target - Class 1,2,3

- Wire to lead-land interface solder connection is equal to (L).

Acceptable - Class 1,2,3

- Minimum length of the wire to lead-land interface solder connection is 75% of (L) (height of the J lead).
- The wire end does not extend past the knee of the component lead.

Defect - Class 1,2,3

- Wire to lead-land interface solder connection is less than 75% of (L).
- The wire end extends past the knee of the component lead.
- Wire violates minimum electrical clearance.

11.2.5.4 Jumper Wires – SMT – Vacant Land

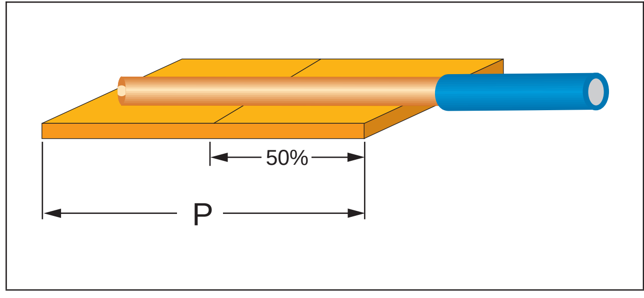


Figure 11-49

Target - Class 1,2,3

- Lead is positioned parallel to longest dimension of the land.
- Lead length and solder fillet equal to (P).

Acceptable - Class 1,2,3

- Minimum length of the wire to lead-land interface solder connection is 50% of (P).

Defect - Class 1,2,3

- Wire to lead-land interface solder connection length is less than 50% of (P).
- Wire violates minimum electrical clearance.

11.3 Component Mounting – Connector Wire Dress Strain/Stress Relief

Wires connecting to multi-contact connectors have slack adjusted to preclude stress of individual wires.

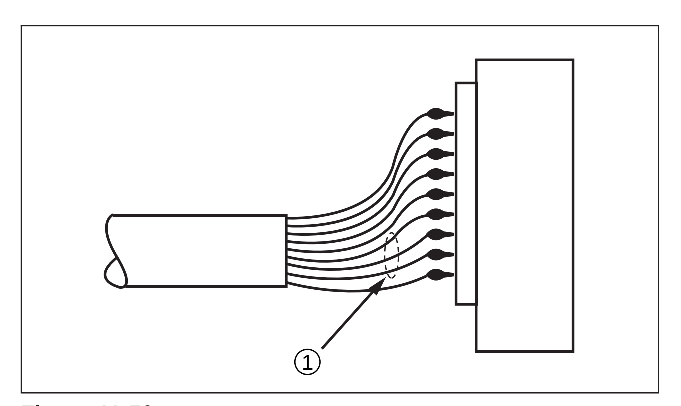


Figure 11-50
1. Lead dress is more critical on these wires

Acceptable - Class 1,2,3

- Wires exiting connector are positioned as they would be at installation.
- All wires are dressed with even bends to prevent stress at contact connections.
- Shortest wires are in direct line with center axis of cable.

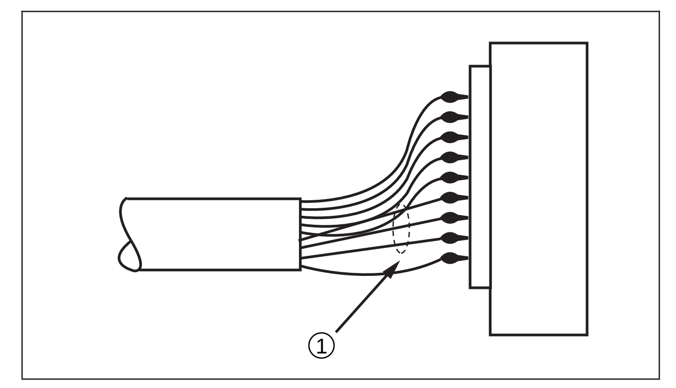


Figure 11-51
1. Leads are stressed

Defect - Class 1

- Wires are separated from the connector.

Defect - Class 2,3

- Slack is inadequate to prevent stress of individual wires.

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12 High Voltage

This section provides the unique criteria for soldered connections that are subject to high voltages, see 1.4.6.

The following topics are addressed in this section:

12.1 High Voltage – Terminals

12.1.1 High Voltage – Terminals – Wire/Leads

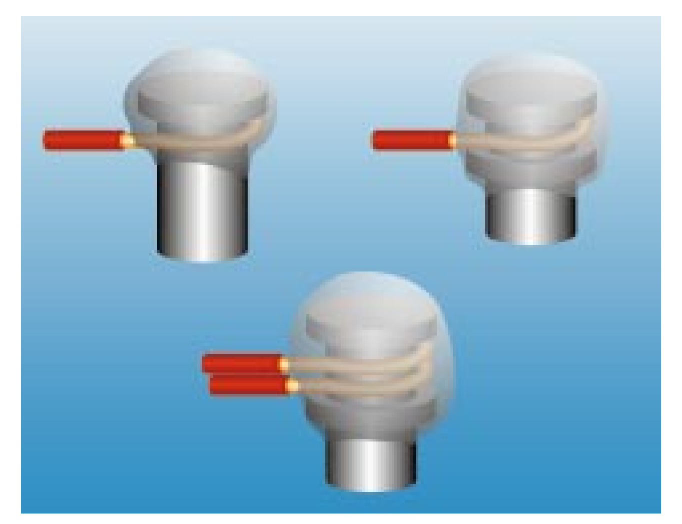


Figure 12-1

Target - Class 1,2,3

- Balled solder connection has a completely rounded, continuous and smooth profile.
- No evidence of sharp edges, solder points, icicles, inclusions (foreign material) or wire strands.
- Insulation clearance as close to the solder connection as possible without being embedded.

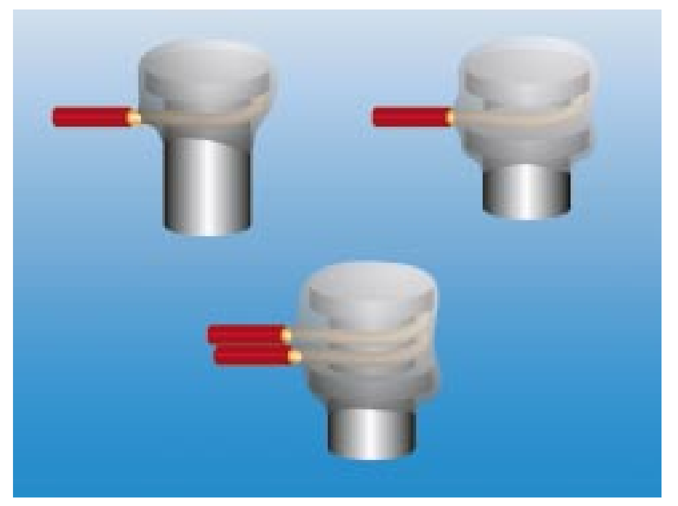


Figure 12-2

Acceptable - Class 1,2,3

- Solder connection has an egg-shaped, spherical or oval profile that follows the contour of terminal and wire wrap.
- No evidence of sharp edges, solder points, icicles, inclusions (foreign material) or wire strands.
- Solder connections may have evidence of some layering or reflow lines.
- Balled solder connection does not exceed specified height requirements.
- Insulation clearance one wire diameter maximum.

12.1.1 High Voltage – Terminals – Wires/Leads (cont.)

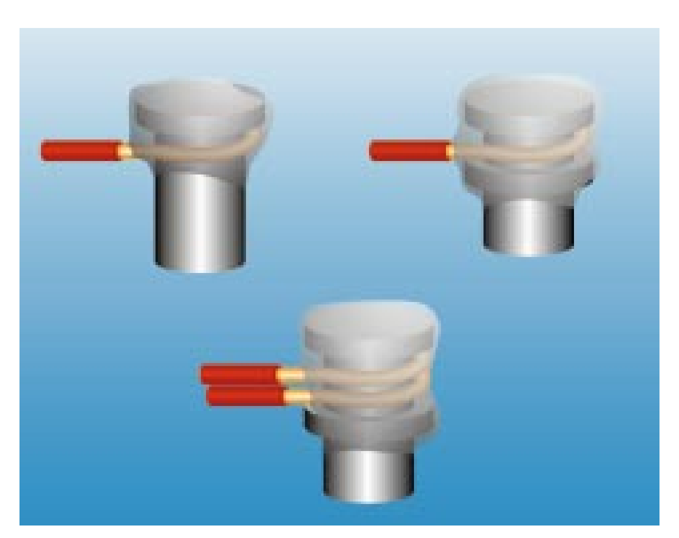


Figure 12-3

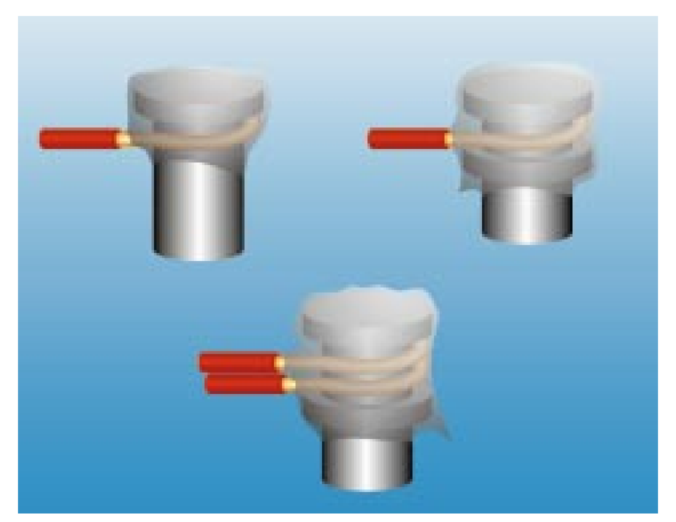


Figure 12-4

Defect - Class 1,2,3

- Solder follows contour of terminal and wire wrap but there is evidence of the sharp edge of the terminal protruding.
- Solder is round and continuous but there is evidence of solder peaks.
- Evidence of edges not smooth and round with nicks or crevices.
- Evidence of wire strands not completely covered or discernible in the solder connection.

12.1.2 High Voltage – Terminals – Bottom Terminations

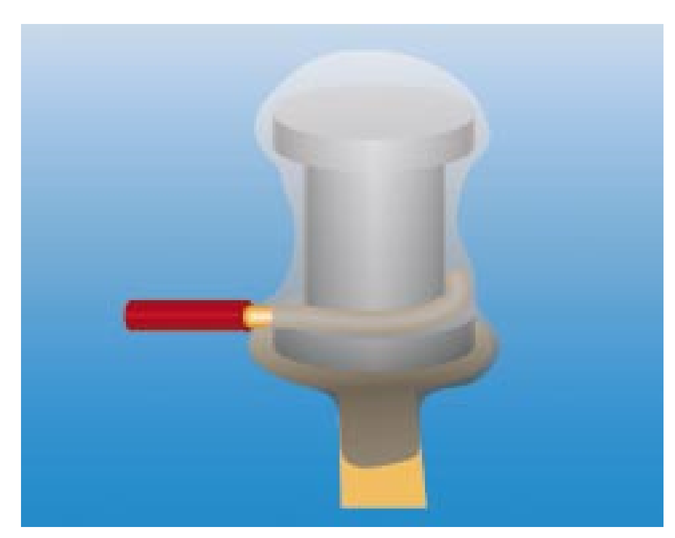


Figure 12-5

Acceptable - Class 1,2,3

- Wire/lead outline is discernible with a smooth flow of solder on wire/lead and terminal. Individual strands may be discernible.
- No evidence of sharp edges, solder points, icicles, or inclusions (foreign material).
- Balled solder connection does not exceed specified height requirements and meets all acceptable criteria for ball soldering.

Defect - Class 1,2,3

- Discernible sharp edges, solder points, icicles, or inclusions (foreign material).
- Balled solder exceeds specified height requirements.

12.1.3 High Voltage – Terminals – Unused

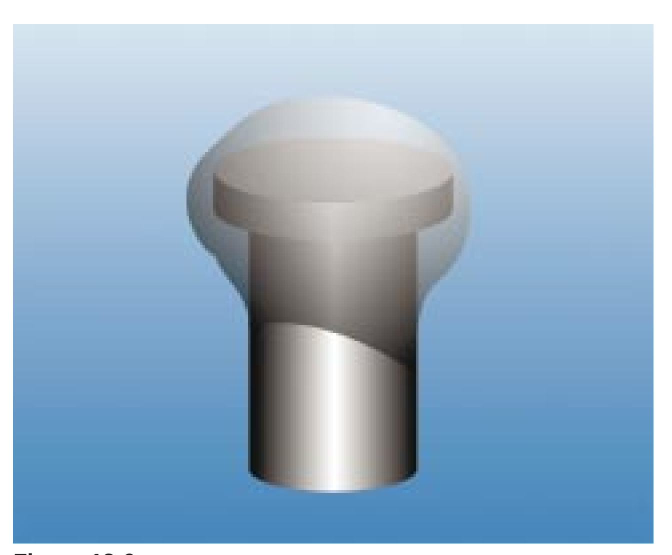


Figure 12-6

Acceptable - Class 1,2,3

- All sharp edges of the terminal are completely covered with a continuous smooth ball of solder.

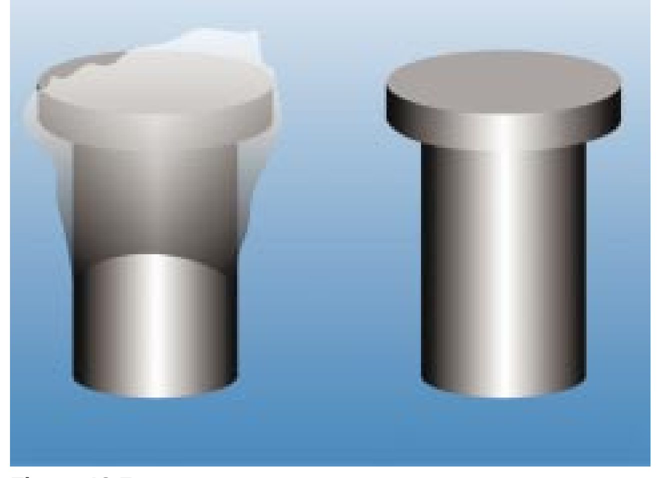


Figure 12-7

Defect - Class 1,2,3

- Solder is continuous but there is evidence of solder peaks, icicles or sharp turret edges protruding.
- Terminal lug is void of solder.

12.2 High Voltage – Solder Cups

12.2.1 High Voltage – Solder Cups – Wires/Leads

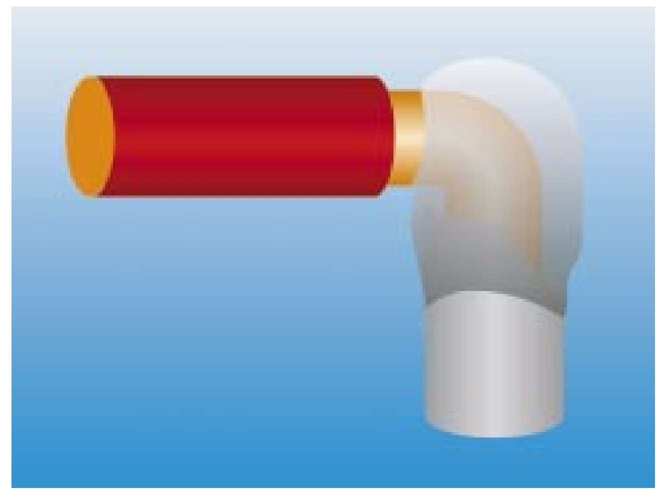


Figure 12-8

Acceptable - Class 1,2,3

- Solder connection has an egg-shaped, spherical or oval profile that follows the contour of wire wrap. No evidence of sharp edges, solder points, icicles, inclusions (foreign material) or wire strands.
- Balled solder connection does not exceed specified height requirements and meets all acceptable criteria for ball soldering.

Defect - Class 1,2,3

- Discernible sharp edges, solder points, icicles, or inclusions (foreign material).
- Insulation clearance greater than one wire diameter.
- Balled solder connection does not comply with height or profile (shape) requirements.

12.2.2 High Voltage – Solder Cups – Unused

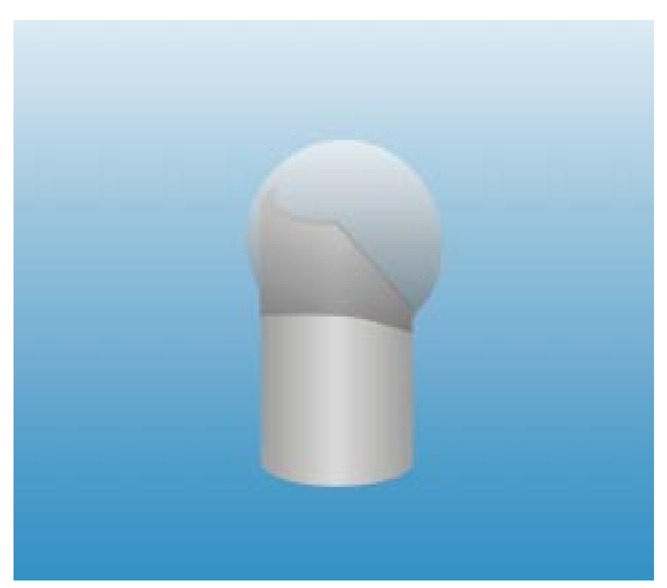


Figure 12-9

Acceptable - Class 1,2,3

- Solder connection has an egg-shaped, spherical or oval profile.
- No evidence of sharp edges, solder points, icicles or inclusions (foreign material).
- Balled solder connection does not exceed specified height requirements and meets all acceptable criteria for ball soldering.

Defect - Class 1,2,3

- Discernible sharp edges, solder points, icicles, or inclusions (foreign material).
- Balled solder connection does not comply with height or profile (shape) requirements.

12.3 High Voltage – Insulation

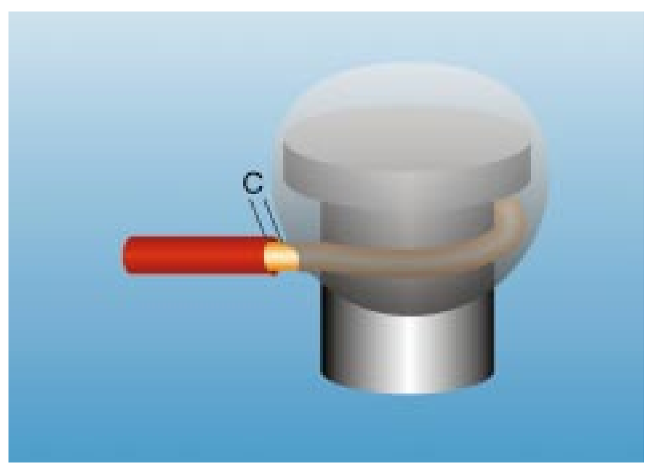


Figure 12-10

Target - Class 1,2,3

- Clearance (C) is minimal so that insulation is close to the solder connection without interfering with formation of the required solder ball.
- Insulation is free of any damage (ragged, charred, melted edges or indentations).

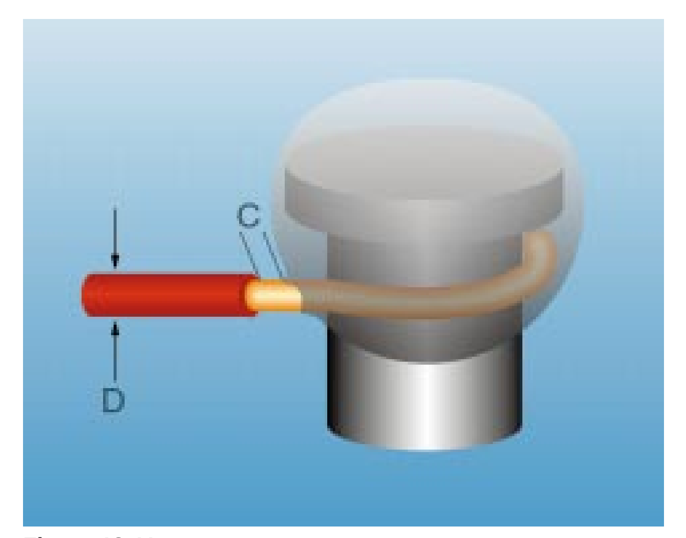


Figure 12-11

Acceptable - Class 1,2,3

- Insulation clearance (C) is less than one overall diameter (D) away from the solder connection.
- No evidence of insulation damage (ragged, charred, melted edges or indentations).

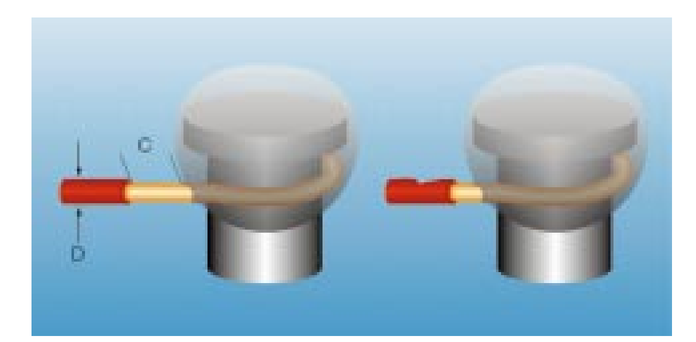


Figure 12-12

Defect - Class 1,2,3

- Insulation clearance (C) is one overall diameter (D) or more.
- Evidence of insulation damage (ragged, charred, melted edges or indentations).
- Insulation interferes with formation of required solder ball.

12.4 High Voltage – Through-Hole Connections

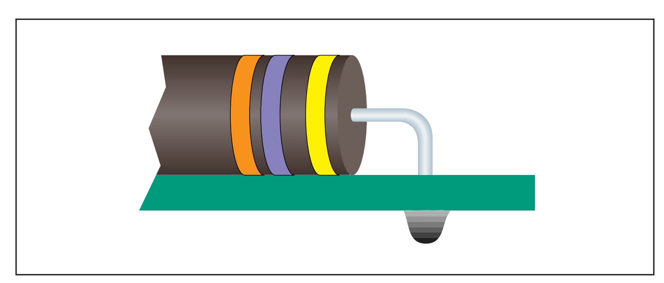


Figure 12-13

Acceptable - Class 1,2,3

- All sharp edges of the component lead are completely covered with a continuous smooth rounded layer of solder forming a solder ball.
- Straight-through leads facilitate ball soldering.
- Balled solder connection does not exceed specified height requirements.

Defect - Class 1,2,3

- Discernible sharp edges, solder points, icicles, or inclusions (foreign material).
- Balled solder connection does not comply with height or profile (shape) requirements.

12.5 High Voltage – Flared Flange Terminals

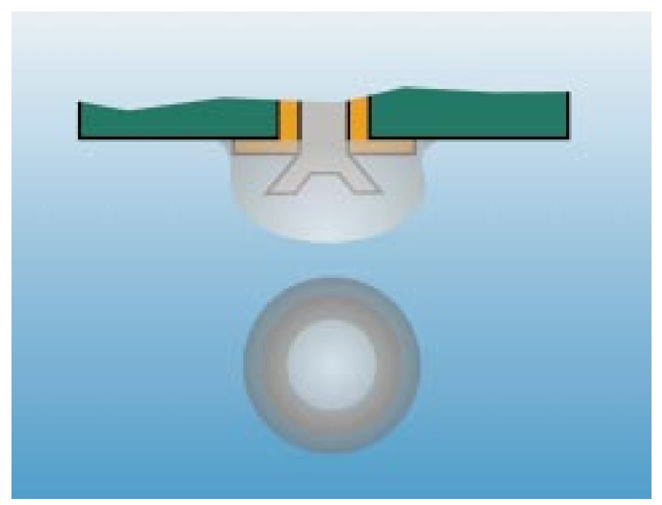


Figure 12-14

Target - Class 1,2,3

- All edges of the terminal are completely covered with a continuous smooth layer of solder forming a solder ball.
- Balled solder connection does not exceed specified height requirements.

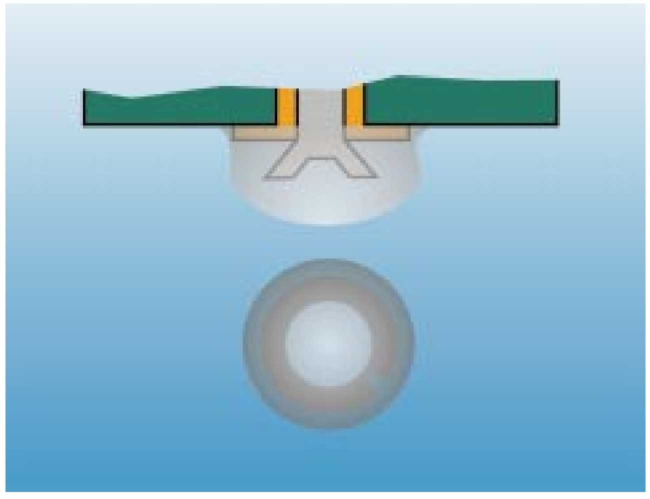


Figure 12-15

Acceptable - Class 1,2,3

- All sharp edges of the terminal's radial split are completely covered with a continuous smooth layer of solder forming a balled solder connection.
- Solder does not exceed specified height requirements.

Defect - Class 1,2,3

- Discernible sharp edges, solder points, icicles, or inclusions (foreign material).
- Balled solder connection does not comply with height or profile (shape) requirements.

12.6 High Voltage – Other Hardware

This section provides the unique requirements of mechanical assemblies that are subject to high voltages.

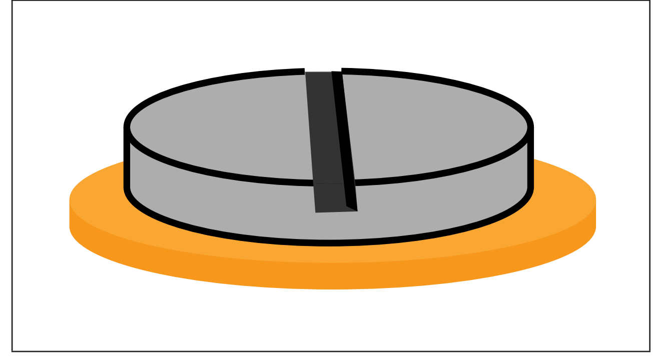


Figure 12-16

Acceptable - Class 1,2,3

- There is no evidence of burrs or frayed edges on the hardware.

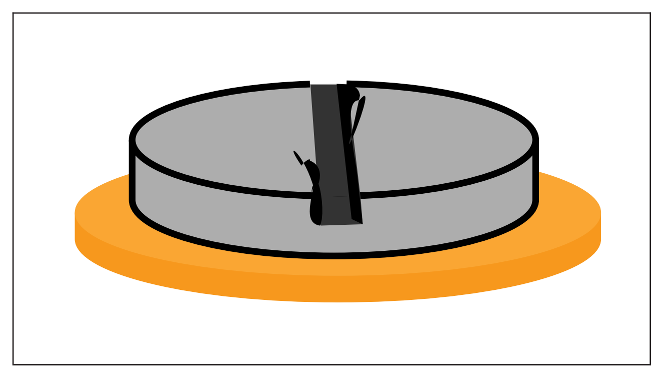


Figure 12-17

Defect - Class 1,2,3

- Hardware has burrs or frayed edges.

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Electrical Conductor Spacing

NOTE: Appendix A is quoted from IPC-2221 Generic Standard on Printed Board Design (February 1998) and is provided for information only. It is current as of publication date of this document. The user has the responsibility to determine the most current revision level of IPC-2221 and specify the specific application to their product. Paragraph and table numbers are from IPC-2221.

The following statement from IPC-2221 applies to this Appendix ONLY: **1.4 Interpretation – "Shall,"** the imperative form of the verb, is used throughout this standard [IPC-A-610D Appendix A] whenever a requirement is intended to express a provision that is mandatory.

IPC-2221 – **6.3 Electrical Clearance** Spacing between conductors on individual layers should be maximized whenever possible. The minimum spacing between conductors, between conductive patterns, layer to layer conductive spaces (z-axis), and between conductive materials (such as conductive markings or mounting hardware) and conductors **shall** be in accordance with Table 6-1, and defined on the master drawing. For additional information on process allowances affecting electrical clearance, see Section 10.

When mixed voltages appear on the same board and they require separate electrical testing, the specific areas **shall** be identified on the master drawing or appropriate test specification. When employing high voltages and especially AC and pulsed voltages greater than 200 volts potential, the dielectric constant and capacitive division effect of the material must be considered in conjunction with the recommended spacing.

For voltages greater than 500V, the (per volt) table values must be added to the 500V values. For example, the electrical spacing for a Type B1 board with 600V is calculated as:

600V - 500V = 100V
0.25 mm + (100V x 0.0025 mm)
= 0.50 mm clearance

When, due to the criticality of the design, the use of other conductor spacings is being considered, the conductor spacing on individual layers (same plane) **shall** be made larger than the minimum spacing required by Table 6-1 whenever possible. Board layout should be planned to allow for the maximum spacing between external layer conductive areas associated with high impedance or high voltage circuits. This will minimize electrical leakage problems resulting from condensed moisture or high humidity. Complete reliance on coatings to maintain high surface resistance between conductors **shall** be avoided.

IPC-2221 – **6.3.1 B1-Internal Conductors** Internal conductor-to-conductor, and conductor-to-plated-through hole electrical clearance requirements at any elevation. See Table 6-1.

IPC-2221 – **Table 6-1 Electrical Conductor Spacing**

Voltage Between Conductors (DC or AC Peaks)	Minimum Spacing						
	Bare Board				Assembly		
	B1	B2	B3	B4	A5	A6	A7
0-15	0.05 mm	0.1 mm	0.1 mm	0.05 mm	0.13 mm	0.13 mm	0.13 mm
16-30	0.05 mm	0.1 mm	0.1 mm	0.05 mm	0.13 mm	0.25 mm	0.13 mm
31-50	0.1 mm	0.6 mm	0.6 mm	0.13 mm	0.13 mm	0.4 mm	0.13 mm
51-100	0.1 mm	0.6 mm	1.5 mm	0.13 mm	0.13 mm	0.5 mm	0.13 mm
101-150	0.2 mm	0.6 mm	3.2 mm	0.4 mm	0.4 mm	0.8 mm	0.4 mm
151-170	0.2 mm	1.25 mm	3.2 mm	0.4 mm	0.4 mm	0.8 mm	0.4 mm
171-250	0.2 mm	1.25 mm	6.4 mm	0.4 mm	0.4 mm	0.8 mm	0.4 mm
251-300	0.2 mm	1.25 mm	12.5 mm	0.4 mm	0.4 mm	0.8 mm	0.8 mm
301-500	0.25 mm	2.5 mm	12.5 mm	0.8 mm	0.8 mm	1.5 mm	0.8 mm
> 500 See para. 6.3 for calc.	0.0025 mm /volt	0.005 mm /volt	0.025 mm /volt	0.00305 mm /volt	0.00305 mm /volt	0.00305 mm /volt	0.00305 mm /volt

B1 - Internal Conductors
B2 - External Conductors, uncoated, sea level to 3050 m
B3 - External Conductors, uncoated, over 3050 m
B4 - External Conductors, with permanent polymer coating (any elevation)
A5 - External Conductors, with conformal coating over assembly (any elevation)
A6 - External Component lead/termination, uncoated
A7 - External Component lead termination, with conformal coating (any elevation)

Electrical Conductor Spacing (cont.)

IPC-2221 – **6.3.2 B2-External Conductors, Uncoated, Sea Level to 3050 m** Electrical clearance requirements for uncoated external conductors are significantly greater than for conductors that will be protected from external contaminants with conformal coating. If the assembled end product is not intended to be conformally coated, the bare board conductor spacing **shall** require the spacing specified in this category for applications from sea level to an elevation of 3050 m. See Table 6-1.

IPC-2221 – **6.3.3 B3-External Conductors, Uncoated, Over 3050 m** External conductors on uncoated bare board applications over 3050 m require even greater electrical spacings than those identified in category B2. See Table 6-1.

IPC-2221 – **6.3.4 B4-External Conductors, with Permanent Polymer Coating (Any Elevation)** When the final assembled board will not be conformally coated, a permanent polymer coating over the conductors on the bare board will allow for conductor spacings less than that of the uncoated boards defined by category B2 and B3. The assembly electrical clearances of lands and leads that are not conformally coated require the electrical clearance requirements stated in category A6 (see Table 6-1). This configuration is not applicable for any application requiring protection from harsh, humid, contaminated environments.

Typical applications are computers, office equipment, and communication equipment, bare boards operating in controlled environments in which the bare boards have a permanent polymer coating on both sides. After they are assembled and soldered the boards are not conformal coated, leaving the solder joint and soldered land uncoated.

Note: All conductors, except for soldering lands, must be completely coated in order to ensure the electrical clearance requirements in this category for coated conductors.

IPC-2221 – **6.3.5 A5-External Conductors, with Conformal Coating Over Assembly (Any Elevation)** External conductors that are intended to be conformal coated in the final assembled configuration, for applications at any elevation, will require the electrical clearances specified in this category.

Typical applications are military products where the entire final assembly will be conformal coated. Permanent polymer coatings are not normally used, except for possible use as a solder resist. However, the compatibility of polymer coating and conformal coating must be considered, if used in combination.

IPC-2221 – **6.3.6 A6-External Component Lead/Termination, Uncoated** External component leads and terminations, that are not conformal coated, require electrical clearances stated in this category.

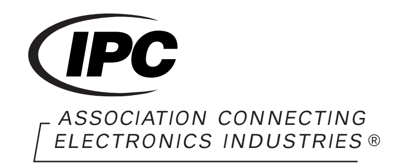
Typical applications are as previously stated in category B4. The B4/A6 combination is most commonly used in commercial, non-harsh environment applications in order to obtain the benefit of high conductor density protected with permanent polymer coating (also solder resist), or where the accessibility to components for rework and repair is not required.

IPC-2221 – **6.3.7 A7-External Component Lead/Termination, with Conformal Coating (Any Elevation)** As in exposed conductors versus coated conductors on bare board, the electrical clearances used on coated component leads and terminations are less than for uncoated leads and terminations.

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IPC-A-610D

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The referenced paragraph number has proven to be:

___ Unclear ___ Too Rigid ___ In Error

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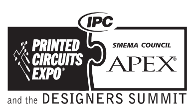
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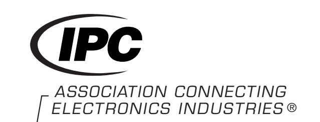
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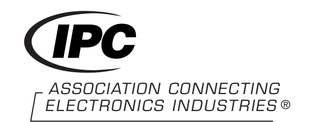
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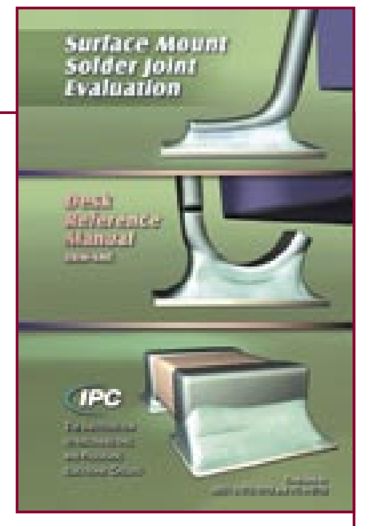
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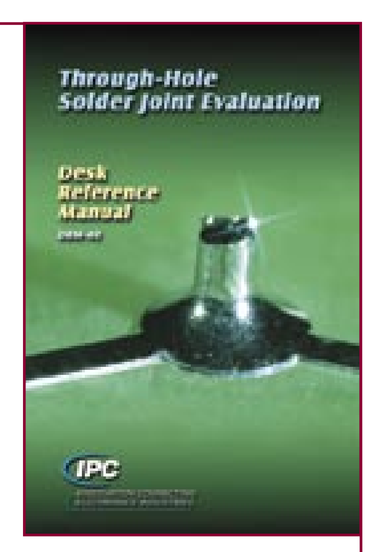
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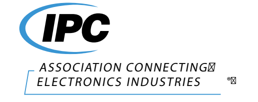
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